Vol. 1. APRIL, 1917. No. 2.

The Journal

OF

The Department of Agriculture

OF

Porto Rico.

San Juan, P. R.
Bureau of Supplies, Printing, and Transportation
1917

VOL. 1. APRIL. 1917. NO. 2.

THE JOURNAL

OF

THE DEPARTMENT OF AGRICULTURE

A change in title of this publication has been made necessary by the change in the Government of Porto Rico, which has placed the Insular Experiment Station and other functions of the Board of Commissioners of Agriculture under the direction of the Commissioner of Agriculture and Labor.

SAN JUAN, P. R.
BUREAU OF SUPPLIES, PRINTING, AND TRANSPORTATION
1917

PUBLISHED BY
THE DEPARTMENT OF AGRICULTURE AND LABOR
UNDER THE DIRECTION OF
W. V. TOWER,
DIRECTOR, INSULAR EXPERIMENT STATION
RIO PIEDRAS, P. R.
JOHN A. STEVENSON, EDITOR.

CONTENTS.

THE WHITE-GRUBS INJURING SUGAR CANE IN PORTO RICO.

I. LIFE-CYCLES OF THE MAY-BEETLES OR MELOLONTHIDS.

By EUGENE G. SMYTH,[1] Acting Entomologist, Insular Experiment Station.

The larvæ of all injurious Scarabaeid beetles are known popularly as white-grubs, and those occurring in Porto Rico are injurious either as grub or as adult to the sugar-cane plant, particularly in the drier sections of the Island. An economical way of controlling these grubs is much desired, and it has been with the object of finding some ultimate method of control that the intensive studies of the life-histories of the species have been made.

Up to the present date ten distinct species of white-grubs have been segregated and studied. Of these, four belong to the genus *Phyllophaga* (better known as *Lachnosterna*) and one to the genus *Phytalus* in the tribe *Melolonthini*, while the other five belong to three genera in the tribe *Dynastini*, which includes the large rhinoceros beetles. The present paper deals only with grubs of the first tribe, known as May-beetles, and is an accumulation of data compiled from observations and life-history studies made by the author during the past four years. The work was conducted at the South Coast Laboratory, located near Guánica Centrale, which is in the heart of the district suffering most from the attack of white-grubs.

The life-cycles and habits of the five species of Dynastids will be given in another paper, to follow this.

THE WHITE-GRUB PROBLEM.

Two facts, that sugar is grown over very extensive areas in Porto Rico, under conditions that are ideal for the development and rapid

[1] Especial credit is due Mr. D. L. Van Dine, the first entomologist of the Experiment Station of the Porto Rico Sugar Growers' Association, and his successor, Mr. Thos. H Jones, for the initial energy given to the study of the white-grub problem in Porto Rico by these gentlemen. The writer wishes to acknowledge the keen interest in the progress of this work and the cooperation given by Dr. L. O. Howard and Dr. W. D. Hunter, of the United States Bureau of Entomology, and by Dr. S. A. Forbes, of the Illinois State University, and their very efficient aid to those who have been detailed to collect parasites in the United States. Credit is also due Dr. Robert D. Glasgow, of Illinois University, for his patience in examining the large series of May-beetles that have been sent him from the Island and in pointing out characters by which they may be separated. The writer wishes to thank Mr. John J. Davis, of West Lafayette, Indiana, for an excellent series of North American species of *Phyllophaga* mounted with genitalia exserted.

multiplication of beetle pests of this sort, and that it is grown continuously year after year on the same ground, without any rotation of crops, render the control of these insects a very serious and very difficult problem. Prior to 1913, the year that the present studies were inaugurated, a considerable amount of experimentation had been made by different parties toward controlling the white-grubs in cane fields, (1) by putting baits, poisons, or fumigants into the soil, (2) by spreading various deterrants on the soil near plants to prevent laying of eggs, (3) by flooding the land with water, or (4) by killing the adult beetles by means of poison sprays applied to the foliage. The results of many of these experiments were negative; and such of them as gave promising results proved inexpedient because of the high cost of materials or of application.

It became increasingly apparent that no hope of a solution of the problem could come from an application of direct methods of control such as these, but that real benefit to the cane-growing industry could come only through the employment of broadly outlined cultural methods of control, based upon an accurate knowledge of the insects' life-histories, or perhaps through the introduction of insect or fungus parasites to prey upon the white-grubs.

Life-history and close field studies of the several species were instituted in May, 1913, and have been continued to the present date. The object constantly in mind has been to determine accurately the length of life-cycles; the time and conditions of oviposition of the eggs; the time of emergence, sexual habits, feeding habits, and habits of flight of the adults; and the inter-relation of these habits and the factors which tend to hasten or retard the time of emergence of the beetles or to affect the amount of damage.

A preliminary report by the author appeared in the Annual Report of this Station for the year 1913–14 (23)[1] and some additional data in the Report for 1914–15 (24). Much of this data is included in the present paper, together with tabulations and graphic charts showing life-cycles, and illustrations showing injury, the early stages, adults and adult parts, parasites, etc., from original photographs.

Methods of control of white-grubs, and results of the introduction of parasites, will be discussed at length in a later number of this publication, when certain experiments and tabulations now in progress will have been completed. Detailed studies of the larval (or grub) and pupal stages, now being made, by which it is hoped

[1] Reference is made by number to "Literature cited," pp. 88–89.

that these stages of the different species may be as easily separated as are at present the adults, will also be presented in another article.

The desire at present is to present the life-cycles of the Porto Rican Melolonthids; to facilitate the separation of the adults of the species, where heretofore they have been hopelessly confused; and to present certain facts in regard to their insect, fungus and bacterial enemies that have come to light in the course of experiments.

What White-Grubs Are.

All beetles pass through a metamorphosis consisting of four stages, egg, larva, pupa, and adult, two of which, egg and pupa, are resting stages and the other two, larva and adult, active stages. The growth of the insect is attained during the larval stage; which means that during this stage the most food is consumed, and hence the most damage committed. It is with the larval stage of the May-beetles and "hard backs," known locally as "caculos," that we are concerned. During this period they gain the name of white-grubs (or "gusanos blancos") through their white color, and their habit of grubbing in the soil.

As the term is used in its broadest sense, white-grubs are considered as including the larvæ of all the injurious Lamellicorn beetles of the family *Scarabaeidae* (3). The word is often used in the United States in a more restricted sense, as referring to the grubs or larvæ of the May-beetles, since these in the States far outnumber all other white-grubs combined (4).

White-grubs may be known from larvæ of other beetles by the following characteristics: (1) subterranean habits, living entirely in tunnels in soil or decaying vegetable matter, and moving about very little; (2) by having the body bent roundly toward the ventral side, so that the ends nearly meet, hence poorly adapted to movement above ground; and (3) by their bodies being thick, soft, and usually glossy white or yellowish with sparse hairs, with a brown, chitinous head and strong mandibles adapted for chewing roots and soil, and with six well-developed legs not used for walking.

White-Grubs Injurious in Other Regions.

Larvæ of Scarabaeid beetles are practically universal in their occurrence as pests, being everywhere known as white-grubs. They are particularly destructive, and often multiply in alarming numbers, in parts of the world where cane is grown, due to conditions which greatly favor their development in such localities. Besides Porto

Rico, they have attained great prominence as pests of cane in the islands of Mauritius and Java, and on the continent of Australia.

White-grubs of the genus *Phyllophaga* are best known as pests to crops in the United States, being widely distributed and having a great many species. As many as forty-two species have been recorded from the single State of Illinois, most of them injurious (8). Damage of the grubs to grass lands, lawns, corn, potatoes, and other crops is often very extensive (4), and the adults have been known to defoliate the timber over whole counties (5, p. 270).

A beetle known as *Ligyrus rugiceps* is a bad pest of cane in Louisiana, having the habit of boring into the stalks at the surface of the ground. In irrigated sections of the Southwest the large green "June bug," *Allorhina mutabilis,* whose larva is a white-grub, does very great damage to fruit.

In Europe members of the genus *Melolontha,* which is closely related to *Phyllophaga*, have been known for over a century as pests, the grubs of one species (*Melolontha melolontha*) frequently causing so much damage to cultivated crops as to necessitate the gathering of the grubs from the fields by hand. In Russia great damage is caused by both grub and adult of a beetle known as *Anisoplia austriaca* (13).

In Australia several white-grubs of the same tribe (known as *Melolonthini*), notably of the genus *Lepidiota,* are the cause of great injury to cane. As much as a shilling a pint has been paid for the grubs from cane fields by the sugar centrals of Queensland. The principal pest is known as *Lepidiota albohirta* (11).

Five species of white-grub, representing five different genera, are injurious to sugar cane in Java; namely, *Holotrichia helleri*, *Adoretes compressus*, *Apogonia destructor*, *Leucopholis rorida,* and *Lepidiota stigma* (10; 14). Trap lights for the adults are used at night.

Various species of the genera *Anomala* and *Adoretes* are destructive in the Hawaiian Islands, in Japan, and in British East Africa.

In the cane-growing sections of India the roots of the plant are subject to attack by white-grubs that are the larvæ of a beetle known as *Serica assamensis.* Other species of white-grubs have also been reported as injurious in India.

Among island possessions, next to Porto Rico, perhaps the most acute injury to cane by white-grubs has been committed by a species known as *Phytalus smithi* in the islands of Barbados and Mauritius. The adult of this beetle differs but slightly from species of the genus *Phyllophaga.* The species is becoming particularly bad in Mauritius, because of its having been introduced there from Barbados without

the wasp parasite, *Tiphia parallela* (2), which in the latter island tends to hold it in control. To illustrate its abundance in Mauritius (where for a while it threatened to paralize the sugar-cane industry), in a period of nine months, from August, 1911, to April, 1912, a total of twenty-seven and one-half millions of grubs, pupæ, and adults (mostly adults) were collected from the sugar-cane fields over an area scarcely three miles square surrounding the Botanic Garden (6).

In the West Indies, aside from Barbados and Porto Rico, cane is known to be injured by a species of *Phyllophaga* in Antigua (26) and by grubs of *Phyllophaga patruelis* in St. Kitts (22). The adults of *P. patens* are said to be very destructive to cacao foliage in St. Vincent (19). A bulletin of the American Museum (15) lists 24 species of *Phyllophaga* and 2 of *Phytalus* from the West Indies, 13 of which are credited to Cuba and 4 to Haiti, but none to Porto Rico.

In British Guiana a beetle known as the "small black hard back," *Dyscinetus bidentatus*, which is the adult of a white-grub, is considered a bad enemy of cane, and a related species, *Ligyrus ebenus*, is occasionally injurious (16). Like the *Ligyrus rugiceps* of Louisiana, it is the adult stage in which damage is done by these two beetles. *Dyscinetus* sometimes attacks young cane shoots in such numbers as to kill them back as fast as they germinate.

Life-History Work on White-Grubs Done Elsewhere.

Because of their subterranean habits, white-grubs are among the most difficult of insects to rear to maturity and to gain any definite knowledge of their changes, or molts. Outside of Europe, prior to 1916, very few species had been reared to maturity and their life-cycles determined. As late as 1913, a bulletin of the U. S. Department of Agriculture (4), in discussion of the genus *Lachnosterna* (*Phyllophaga*), stated: "There is only one published record, involving a single species, in which an individual belonging to this genus has been reared from egg to adult." Since that date, however, considerable breeding work has been done in Indiana by Mr. J. J. Davis, of the U. S. Bureau of Entomology, to whom credit is due for having successfully reared to maturity from the egg eighteen species of the genus, definitely establishing the length of life-cycle of each (5).

In Australia similar difficulties have confronted investigators in this group of insects. In a bulletin of the Bureau of Experiment Stations of Queensland published in 1914 (9), it is stated: "At first rearing was depended upon to give us evidence of the entire period of development, but we have not as yet succeeded in rearing a single

specimen through its stages, but may succeed in doing so by the time the next beetle season arrives."

Outside of Europe, and the work done by Mr. Davis in Indiana, the nearest approach to accuracy in establishing the length of life-cycle of a beetle of the group *Melolonthides* is the work done in Mauritius on *Phytalus smithi* by Mr. d'Emmerez *de Charmoy* (6). He determined the maximum and minimum number of days required for each stage of the life-cycle, but did not determine the length of separate instars of the grub.

So far as known to the writer, nothing has been published heretofore on the larvæ of *Phyllophaga* or related genera which establishes accurately the lengths of instars of the grub.

Life-Cycles of White-Grubs.

It has been known for a number of years that the common cockchafer of Europe, *Melolontha melolontha*, whose grub is the worst white-grub pest of that continent, required a period of three years to pass its life-cycle in the latitude of France and southern Germany, and four years in the latitude of northern Germany.

In the United States it has been taken for granted that certain common species of *Phyllophaga*, such as *P. fusca* and *P. fraterna*, because of the regular periodicity of their appearance in numbers every three years, require that length of time to pass the life-cycle (7). Certain other species in the States, appearing regularly at intervals of two years, were supposed to require that length of time to undergo the change from egg to adult (33). Very recently Mr. Davis has definitely ascertained that out of eighteen species of *Phyllophaga* reared from egg to adult in the latitude of central Indiana eleven of them have an invariable three-year life-cycle, one (*Phyllophaga tristis*) has an invariable two-year life-cycle, three have a life-cycle varying from two to three years, and two others a cycle varying from three to four years (5).

The establishment of the fact that all four Porto Rican species of *Phyllophaga*, as well as the single species of *Phytalus*, require but a year or somewhat less to undergo the life changes, will be somewhat of a surprise to students of this group of insects. Yet it is what should be expected in a tropical or sub-tropical climate.

These facts are paralleled, in a measure, by those established by Mr. De Charmoy with regard to the life-history of *Phytalus smithi* in Mauritius—with the difference that he found the life-cycle of that species to occupy somewhat over a year (6).

Enemies of White-Grubs.

The natural enemies of white-grubs fall into three classes, namely, animals (including birds and lizards), insects (including mites and worms), and plants (fungus and bacterial). A noted French naturalist has said of the common European white-grub that "efficacious animal parasites of the insect are unknown" (29).

Fortunately, in Porto Rico, all three groups of parasites are present; yet as all of these are insufficient to keep white-grubs in check, it is necessary—when other means of control fail—to supplant these, or rather assist them, by the introduction of parasites not already occurring here.

ANIMAL AND BIRD ENEMIES OF GRUBS IN PORTO RICO.

There are in Porto Rico no small mammals known to prey extensively upon white-grubs or May-beetles as do skunks in the United States. Perhaps field mice and rats eat occasional specimens, but as an agency of control they can be of no great economic importance.

An attempt was made in 1913 by one of the sugar centrals of the Island to introduce and acclimate the European hedgehog, quite a number of which were brought over from Germany for the purpose. Most unfortunately, they were liberated in a hot and arid part of the Island, so different from their native humid and shady habitat that they did not survive. In confinement they ate May-beetles voraciously when fed them, but were not seen to burrow deep enough into the soil to reach the grubs; and it is a question if they would have proved of real economic importance as a control measure had they become successfully established.

In Porto Rico insect-feeding lizards are extremely abundant. The majority of these, which belong to the genus *Anolis,* are too small to devour the larger May-beetles. In addition they are diurnal in habit and live entirely above ground, usually upon plant foliage or trees. There is one large ground lizard, however, called "siguana" (*Ameiva exul*), which is largely burrowing in habit and which, it is believed, feeds to some extent upon white-grubs and May-beetles. It inhabits the sandier soils, and by one close observer has been often seen devouring changas, or mole-crickets. Certainly, white-grubs would be far easier prey for it than the active changas; and it is altogether probable that they do constitute a part of its diet.

Of birds, there are at least three species on the Island that are important enemies of the white-grubs and May-beetles, and a fourth that is worthy of mention. These are, in the order of their importance

as enemies of grubs: (1) the Porto Rican blackbird or "mosambique," *Holoquiscalus brachypterus;* (2) the bare-legged owl or "múcaro," *Gymnasio nudipes nudipes;* (3) the little blue heron or "garza azul," *Florida caerulea caerulescens;* and (4) the mangrove cuckoo or "pájaro bobo," *Coccyzus minor nesiotes.* In Bulletin No. 15 of this Station, entitled "Birds of Porto Rico," by Alex Wetmore, the results are given of an examination of the stomach contents of these four species of birds as follows (the figures being the per cent. of white-grub and May-beetle remains to entire contents of all stomachs examined): blackbird, 1.61 per cent.; bare-legged owl, 24.4 per cent.; little blue heron, 1 per cent.; and mangrove cuckoo, .05 per cent. Of twenty-three blackbird stomachs collected largely in cane fields under cultivation, the proportion of white-grub and May-beetle remains to total contents was 9.47 per cent. Certainly, after a day of activity of the birds behind the plows in cane fields, the proportion would be much higher than this.

Another bird, known as the "ani," or "Juda bird," has been often spoken of as eating white-grubs; but the bulletin above referred to does not give account of the finding of any white-grub or May-beetle remains in stomachs of this species. And, moreover, common as the bird is about cane fields, it is a rather shy species and is seldom seen following the plows.

The blackbird, or "mosanbique," is placed as the most important bird enemy of white-grubs because of its great abundance in those parts of the Island where the white-grubs are most injurious, namely, in the arid coast districts. It is a very common sight to observe considerable flocks of these birds following the plows and picking up grubs when fields cleared of cane are being broken up. Figure 1, of Plate VI, is from a photograph taken by the author at Santa Rita, near Guánica Centrale, during the winter plowing season. By actual observation and count, it was shown that over 90 per cent of the grubs exposed to light by the plows are picked up by these birds, so that the employment of peons to follow the plows and pick grubs is quite unnecessary in that district. When it is considered that a bird is able to consume more than the equivalent of its own weight of food in twenty-four hours, and that blackbirds during the plowing season of five to six months subsist almost wholly upon grubs, one may appreciate the vast numbers of grubs that they consume.

INSECT ENEMIES OF GRUBS OCCURRING ON THE ISLAND.

Among the insect enemies of the May-beetle larvæ and related white-grubs there are at least nine species known to occur on the

Island, all native, which makes an unusually good representation as compared with other islands of the West Indies. These fall into three groups, six of them being Hymenopterous (all Scoliid), two of them Dipterous (both Tachinid), and one Coleopterous (Elaterid). Those of the first and last groups attack only the grubs, while the Diptera attack only the adults.

We may add to these four others, all of which have been observed attacking the grubs (or eggs) under laboratory conditions only. One of them is a white nematode, not exceeding 5 or 6 mm. in length, which on several occasions gave trouble by destroying the eggs in experimental jars. More troublesome than the nematodes was a species of minute, globular white mite (*Tyroglyphus* sp. ?), which attacked all stages of the beetles, from egg to adult, and was the cause of a high per cent of mortality in experimental jars and boxes.

Of minor importance were a Staphylinid beetle larva (species undetermined) and a wireworm, the young of an Elaterid beetle (*Monocrepidius* sp.), both of which were observed to feed upon May-beetle eggs in experimental jars. Both were introduced with earth enriched with manure, and it is not believed they would ever cause mortality of eggs under natural conditions in the field.

The following list will serve as a guide to the known white-grub parasites of the Island. The more important of them will be discussed later under the species they attack.

No.	FAMILY	SPECIES [1]	HABITAT	ABUNDANCE
1	*Scoliidæ*	*Elis sexcincta* Fab.	General	Common
2	"	" *xanthonotus* Roh.	Northern	"
3	"	*Campsomeris dorsata* Fab.	General	Abundant
4	"	" *trifasciata* Fab.	Northern	Common
5	"	" *pyrura* Roh.	Southern	Rare
6	"	*Scolia atrata* Fab.	Western	"
7	*Tachinidæ*	*Cryptomeigenia aurifacies* Wal.	Northern and Western	Abundant
8	"	*Eutrixoides jonesii* Wal.	Western	Rare
9	*Elateridæ*	*Pyrophorus luminosus* Ill.	Northern and Western	Abundant

[1] The determinations of the wasps (except *Scolia atrata* Fab., which was determined by the Am. Mus. Nat. Hist.) in this list were made by S. A. Rohwer, of the flies by W. R. Walton, and of the beetle by E. A. Schwarz.

The only one of these parasites which has been found hyperparasitized is *Campsomeris dorsata* Feb., a dead adult of which was found at Santa Rita containing a single Dipterous puparium, about 5 mm. long, from which issued, on June 18, 1913, ten small Chalcidids, which have not been determined.

Outside of Porto Rico, *Elis sexcincta* Fab. (?) was collected by the writer in great abundance on Mona Island in December, 1913, where it occurred on the leaves of corn infested with *Peregrinus maidis*. *Campsomeris pyrura* Roh. was taken commonly at Higueral, Santo Domingo. in February, 1914, and a few also were taken on Mona Island.

EFFICIENCY OF WHITE-GRUB PARASITES IN PORTO RICO.

Our knowledge of the white-grub parasites of the Island is at present very limited, and much is yet to be done in the working out of hosts and life-histories of the various species.

Of the nine species of white-grub parasites listed above, there is direct evidence of only one of them destroying the grubs of *Phyllophaga*. This is the Elaterid beetle, *Pyrophorus luminosus* Ill., larvæ of which have been fed upon *Phyllophaga* grubs for long periods in confinement in the insectary. Field observations of this wireworm preying upon white-grubs are still too few to make any definite statement as to its value in white-grub control. The beetle is extremely abundant in the spring and summer on the north and west sides of the Island; if true that it destroys white-grubs under outdoor conditions, its presence may perhaps account in part for the lesser injury from grubs in the sections where it abounds.

Some of our earlier notes (for the year 1911) credit *Campsomeris dorsata* Fab. with being a parasite of *Phyllophaga* grubs (30. p. 36). But in all cases the grub determinations were doubtful. It seems probable that the parasitized grubs in question, if not of *Dyscinetus*, which closely resembles *Phyllophaga* in the larval stage, were of *Ligyrus tumulosus* Burm., whose grub is abundantly parasitized at all seasons by *Campsomeris*.

It may develop, with additional observation, that the two species of *Elis* occurring here one or both parasitize grubs of *Phyllophaga* in restricted localities. Yet the strange fact remains that of thousands of *Phyllophaga* grubs collected in cane fields, and examined by the writer, not one has ever been found parasitized by a Scoliid egg or larva.

THE TACHINID PARASITES.

Our present knowledge of white-grub conditions leads to a belief that the most important and active agency in the control of white-grubs in Porto Rico is the work of the two Tachinid flies, *Cryptomeigenia aurifacies* Wal. (Pl. VII, fig. 7) and *Eutrixoides jonesii* Wal., upon the adults. Like the *Pyrophorus* beetle, these flies seem

confined to the more humid sections of the north and west coasts—which may further explain why white-grubs are less abundant and destructive in these sections than on the dry south coast, where there are few or no Tachinid parasites or *Pyrophorus* beetles. An account of the discovery of these two flies will be found on page 37 of the Second Report of the Board of Commissioners of Agriculture of Porto Rico (30). The adult and pupal case of *Cryptomeigenia aurifacies* Wal., which is the commoner species, are shown on Plate VII, figure 7.

INTRODUCTION OF PARASITES.

From many observations and estimates, it is evident that the mortality to white-grubs from parasites in Porto Rico is very low, and that the native parasites are quite insufficient to cope with these pests, which continue to increase wherever cane is grown. The only hope in relieving this condition has seemed to be in the introduction of other white-grub and May-beetle parasites from abroad. Among the first efforts made in the artificial control of the white-grubs of the Island, therefore, were attempts to introduce foreign parasites, which it was hoped would establish themselves successfully on the new host grubs (27, p. 52).

The logical field for securing white-grub and May-beetle parasites was the United States, not alone because they are better known there than elsewhere in the western hemisphere, but also because, in a large territory like the American continent, parasites have wider distribution, and necessary conditions for collection that cannot be encountered in one locality may be met in another. For convenience of handling, collection of grub parasites is usually made of the cocoon stage from the soil, and is therefore done during plowing time. Plowing time in the States shifts from south to north with the advance of the season, thus permitting the collecting to extend over a much longer period than would be possible in limited areas.

Parasite introduction was initiated in 1911 by Mr. D. L. Van Dine, then entomologist of the Porto Rico Sugar Producers' Experiment Statiton. His reports of the early progress of the work will be found in the First and Second Reports of the Board of Commissioners of Agriculture (29; 30).

An entomological collaborator was employed by the Board for the purpose of collecting living white-grub parasites, or parasite cocoons, in the States and shipping them to Porto Rico in living condition. The position was first held by Mr. C. E. Hood, who began work on June 16, 1911, and later by Mr. Geo. N. Wolcott. The work

was continued up to October, 1914, the majority of the parasites having been collected in the State of Illinois. During this time a total of about 2,500 parasites (including adults, larvæ and pupæ) were received from these workers, and of these a total of about 1,000 parasites were liberated. The great majority of these were wasps belonging to the genus Tiphia. (See Plate VII, fig. 8.) In addition to the parasites sent here, a number of cocoons of Elis were sent to Mr. O. H. Swezey in Hawaii for use against the white-grubs of those islands.

Following is a list of the better known *Phyllophaga* parasites occurring in North America. From these it was necessary for the parasite collectors to choose those species which could be most easily collected in numbers and sent to the Island.

NORTH AMERICAN PARASITES OF *Phyllophaga* LARVÆ.

1. *Tiphia inornata* Say.—A black Scoliid wasp of wide distribution in the States, and possibly infesting the grubs of several species of May-beetles (7, 21, 35). It is the commonest and best-known American parasite of white-grubs. There are several related species, for the most part feebly differentiated from it. (In Europe a species called *Tiphia femorata* attacks white-grubs of several *Melolonthids* (32); another, *Tiphia parallela,* attacks *Phytalus smithi in* Barbados (18), and *Dyscinetus bidentatus* in Demarara) (16).

2. *Elis* (*Myzine*) *5-cincta* Fab.—A common Scoliid white-grub parasite occurring in the Central States, but more local in distribution than the *Tiphia.* There are other species of this genus found in restricted localities.

3. *Ophion bifoveolatum.*—An Ichneumonid wasp that parasitizes white-grubs, but is far less common in most localities than the Scoliid wasps.

4. *Pelecinus polyturator.*—A Proctotrypoid wasp, the female of which has a very long body, as if for penetrating the soil for oviposition. It has been reared by Professor Forbes from May-beetle larvæ and, being very abundant in timber land in some districts of the Middle West, may be a more important enemy of white-grubs than is generally known.

5. *Sparnopolius fulvus* Wied.—A small Bombyliid fly parasitic upon white-grubs, of only secondary importance, however.

6. *Promachus vertebratus* Say.—A large Asilid fly, larvæ of which are predacious upon white-grubs. The species is said by Mr. J. J. Davis (5) to be a prominent grub enemy in certain parts of Wisconsin. A nearly related species in the East is *Promachus fitchii* O. S.

7. *Microphthalma disjuncta* Wied. *Megaprosopis michiganensis*).—A large Tachinid fly parasite of white-grubs, said to be common in the Central Western States. Mr. Vassiliev reports the same Tachinid as parasitizing the grubs of *Anisoplia austriaca*, and three other species, in southern Russia (32). Another closely related species in the States is *Microphthalma pruinosa*, also of wide distribution.

8. *Mochlosoma* (*Prosena*) *lacertosa* V. d. W.—This large Dexiid fly was reported by J. H. T. Townsend as issuing in great numbers from the puparia in the soil in pasture lands near Colonia García, Chihuahua, northern Mexico, and he was certain they were parasitizing white-grub (29). The determination of the fly was made by Doctor Coquillet. (A related species, *Prosena siberita*, attacks grubs of *Adoretes compressus* in Java.) (10).

9. *Ptilodexia* (*Estheria*) *tibialis* Desv.—Another Dexiid fly, which Davis mentions as parasitizing white-grubs in Texas (5, p. 271).

10. *Pyrophorus* sp.—An Elaterid beetle, very abundant in southern Texas, the larvæ of which are predacious upon a common white-grub of that section.

Parasites of the Adults.

11. *Pyrgota undata* Wied.—An Ortalid fly, the commonest and most efficient parasite of adult May-beetles in the Central States, and also generally distributed. Another species, more local in habitat, is *Pyrgota valida* Har. These are nocturnal in habits, as are also the following *Tachinid* flies.

12. *Cryptomeigenia theutis* Walk.—A Tachinid fly quite commonly infesting the bodies of adult May-beetles in some sections of the United States. The only other representative of the genus known to the writer is the common Porto Rican species, *Cryptomeigenia aurifacies* Wal.

13. *Eutrixa exile* Coq. (*Nemoraea masuria* Walk.)—Another Tachinid fly parasitizing May-beetles. It has habits like the preceding, infesting the beetle body.

14. *Biomyia lachnosternae*.—This Tachinid, identified by Mr. Walton, is the one referred to by Dr. Forbes as *Viviana* sp. in Bul. 116 of the Illinois Agr. Exp. Station, according to Mr. J. J. Davis (5). It was reared from the adult of *Phyllophaga crenulata*.

15. *Sarcophaga helicis* Towns.—This Sarcophagid fly was reared from adults of *Phyllophaga arcuata* collected at Washington, D. C.

Simultaneous with the introduction of insect parasites of white-grubs into Porto Rico, Mr. Van Dine initiated an attempt to introduce certain entomogenous fungi that are known to attack white-grubs and beetles related to the May-beetles in other regions (27; 29) Cultures were received both from Europe and from Hawaii, the species of most importance from the former place being *Botrytis tenella* (or *Isaria densa*), which is reputed to have been used with so much success at one time against the larvæ of *Melolontha* in France (29, p. 42).

From cultures received from Hawaii one species, that known as the Samoan fungus, or green muscardine fungus, *Metarrhizium anisopliae,* was succeessfully established on the Island, and large numbers of May-beetles were infected by means of soil inoculations (29) (See Pl. IV, figs. 7, 8, 9.) It was later learned that a local form of this fungus had already existed on the Island prior to the introductions from Hawaii, as grubs and beetles infested with the fungus were found in parts very remote from where liberations of spores had been made (12; 30).

Several liberations of the spores of *Metarrhizium* have been made by the pathologists of the Station, Mr. J. R. Johnston and Mr. J. A. Stevenson, the spore material having been grown in large cabinets on a scale surpassed only by the extensive liberations of *Metarrhizium* against the frog-hopper in Trinidad. The results of these liberations have been somewhat variable (25).

Method of Rearing Grubs.

Because of their subterranean habits, white-grubs are very difficult to rear to maturity, and to observe their molts. Living in tunnels in the soil, they are apt to be injured or set back in growth by being disturbed. Difficulty rests also in their requiring so long to reach maturity, their life-cycles in many cases covering a period of more than a year, which promotes the possibility of their succumbing to fungus and other diseases contracted through artificial means.

It is possible that the difficulties of rearing white-grubs in confinement are less felt in the tropics than in temperate climates because of there being no period of cold weather through which the grubs must be given special care and treatment. This advantage, however, is in part counteracted by the increased activity of certain parasitic fungi and other diseases that attack the grubs in warmer climates.

Perhaps the most careful methods of rearing grubs in temperate climates have been worked out by Mr. J. J. Davis at Lafayette, Indiana (5). His method consists, briefly, in the use of flower pots twelve to sixteen inches in diameter and height, or of cylinders made of metal and wire screening, twenty inches in diameter and two and one-half feet in depth, which are inserted into the ground in such a way as to give natural conditions of moisture and drainage. Necessarily cages such as these, even though each many contain several grubs, require a rather large amount of space for the rearing of large numbers of grubs; and it must be remembered that only in the results from rearing large numbers of grubs can accurate data be obtained. Under tropical conditions, where there is no winter to contend with, methods requiring much less space have been found quite satisfactory and in most respects preferable.

Methods of rearing employed by the writer consisted at first in the use of flower pots six inches in diameter and of glass battery jars. The objection to the pots was that they required dumping of the earth in order to view the grubs, which meant disturbance and often injury to the grubs. The objection to the jars was that they allowed for no drainage, and the soil became sour, thus permitting mites and nematodes to breed. Furthermore, in glass jars grubs would seldom remain near enough to the glass to be seen, so there was no advantage gained.

In all respects the most convenient method was found in the use of two and one-half and three-inch round, seamless tin boxes, one and one-quarter inches high. One or two grubs were kept in each box, the larger grubs being kept in larger boxes. These boxes were conveniently kept in piles and tiers, and were opened and the contents examined regularly at intervals of several days to a week or more. Pupæ were examined almost daily. To prevent rust boxes were first lined with a thin coating of paraffin. Moisture was regulated not by adding water to the box, which experience proved was dangerous, but by using sifted earth of the right dampness to begin with, and renewing the earth when it became dry or sour.

Food was supplied by adding a kernel of corn to each box. A new kernel was never added until the old one had been entirely consumed, germinating roots and all, as it was found that greater danger came from over feeding than from under feeding. Too much food in a box always led to an accumulation of mites (*Tyroglyphus* sp.?), which would attack and often sicken the grub, finally causing its death unless the mites were carefully brushed off and fresh earth supplied. In absence of corn, a small section of cane could be fed;

but cane quickly soured and nearly always gave rise to mites, so that use of corn was preferable.

Movements of the grub in a can have a tendency to pack the earth, so that by careful manipulation of a knife blade the top earth may be removed and the grub's tunnel exposed. A tunnel averages three to four times the length of the grub's body; and when one part of the tunnel is opened the grub rushes to the other extremity, so that there is small danger of injury. The grub may thus be viewed without disturbing it to any great extent.

When a grub is first added to a can, the latter is filled even full with sifted (not too fine) moist earth, and with the thumb or finger a pit is compressed in the soil, into which the grub is placed. It is never covered with earth.

There is little to be improved upon in the matter of convenience in the methods described here, provided care is taken; nor is there any more divergence from natural, outdoor conditions than would be the case in using larger boxes, jars, or pots. Check experiments proved that there was no difference in the time of emergence between adults from grubs in tin boxes and adults from grubs outdoors, provided a grub escaped the attack of mites, fungus, or bacterial disease. The presence of these diseases in small boxes was in most cases induced by over feeding, excessive moisture, or careless handling.

Check experiments for each species were run in large outdoor rearing cages, containing a depth of six to ten inches of earth in which was grown cane or corn as food. Cages were of uniform size, three by six feet and three feet high, screen covered with wooden bottoms, set up on posts as protection from ants and rodents. Adults were usually liberated in them in quantity, one species in each, at about the same time that other series were confined in jars for eggs. After a week or so of confinement adults were removed, eggs having been deposited in the soil. The cage remained undisturbed, except to be regularly watered and occasionally replanted to fresh cane or corn, until sufficient time had elapsed for grubs to mature and adults to issue.

In these cages the time required for emergence tallied very closely with the time required for grubs confined in tin boxes, showing that soil conditions in the smaller tin boxes did not change the time of emergence from normal.

In the case of one species, *Phytalus insularis,* no larvæ reared in tin boxes were successfully brought to maturity, so that results obtained

from the large outdoor cages were depended upon in determining the length of the life-cycle.

OVIPOSITION AND HANDLING OF EGGS.

Some difficulty was experienced in determining the possible duration of oviposition by female adults. When beetles were confined "en masse," that is, a number in a cage or jar, there was usually a heavy mortality, which may have been due to the fungus disease, *Metarrhizium*, being able to communicate itself from one beetle to another.

The obstacle to confining females singly for oviposition may be realized when one takes into account the difficulty of giving the beetle sufficient living food material and freedom of movement, and at the same time restricting the amount of soil to a quantity not too large to sift and examine in a reasonable length of time. Beetles had to be confined in numbers, and the earth examined at frequent intervals, to give oviposition records value.

At first beetles were confined over potted plants; but it was found too difficult to extract eggs from among roots without crushing them. Also, the effort of supplying a fresh plant for each beetle at each examination of the soil was considerable.

Later experience showed that a beetle requires neither to fly nor climb in order to maintain a fairly normal existence in confinement. A method devised was to confine each female in a small glass battery jar, four inches in diameter by six inches high, in the bottom of which was placed two inches of moist earth, sifted to a fineness somewhat smaller than the size of the eggs, so that the latter were easily sifted out. The soil was packed lightly with the hand, and a few strips or sections of banana leaf put in above the soil as food for the beetle, being first dipped in water, after which they remained green for two or three days and were relished by the beetles.

It was not found necessary to confine adults in pairs in order to secure fertile eggs. There was no advantage in doing so, as copulation never took place to the writer's knowledge in small jars. Beetles collected immediately following copulation remained fertile for two months or more. No cases were observed of infertile eggs from females confined alone, except those from reared females, which of course had never copulated.

The first method devised for rearing the eggs was to place each one in a small pit made with the head of a match in the flat side of a small ball of damp soil or mud, and to press a tier of these

against the glass on the inside of a jar, around the circumference of the bottom, so as to expose the eggs to view. The space was filled in with sifted soil even with the tops of the earth balls, another tier added, and so on until all eggs of a lot were placed. Corn was not planted then until all eggs had hatched, as otherwise the germinating roots grew into the egg cavities and smothered the eggs or obscured them from view. Eggs were never put loose into a jar and covered with soil, as they must have room to swell, being laid under natural conditions in small cavities made by the female ovipositor which allow for swelling. (See Plate V, fig. 9, and Plate VI, fig. 3.)

A better and simpler method was to place the eggs over damp soil in shallow glass petri dishes. Being tightly closed, and of small size, these dishes maintained the required humidity, and a great many eggs were thus easily attended to and examined in a short time. As the eggs hatched, the young grubs were removed to tin boxes. With this method, care must be taken of two things: one, that the petri dishes remain in a place of little exposure and of uniform temperature; and two, that the soil be sterile, to insure it against mites and nematodes, to both of whose attack May-beetle eggs seem to be very susceptible.

Boxes for grubs just hatched should have the soil sifted, quite moist, and packed very gently if at all. Small pits were made in the soil with a match, and the grubs placed into these; if placed on the surface of soil they are often unable to penetrate. No planting of corn was required in the boxes until grubs were nearly ready to molt, as very young grubs were observed to feed almost entirely upon organic matter in the soil, and seldom to touch roots.

PUPÆ AND EMERGENCE OF ADULTS.

Before pupating, a May-beetle grub assumes a soft, flabby condition, during which it lies inertly on its back at the bottom of the tunnel. This is known as the prepupal stage. Prior to changing to the prepupa, the grub shortens and somewhat broadens its tunnel, making it very hard and smooth on the inside. In the cell so formed it undergoes the change to pupa and then to adult.

Whenever possible, it was found preferable to leave the pupa in its natural pupal cell, simply making an opening in the top of the cell through which it could be viewed. The use of the shallow tin boxes made this possible. When necessary, however, a smooth artificial cell open at the top was made in the soil in a tin box, and

the pupa placed in it on its back. Soil during the pupal stage must be kept uniformly moist, and mites must be guarded against.

In the field, pupation takes place usually at a depth of one and one-half to two feet, which is a foot or more deeper than the larva lives, and this going to a lower level is attributed to an instinct on the grub's part to avoid changes of temperature, and disturbances of the soil by plowing, that would take place nearer the surface. It seems, however, that it is simply a provision to so place the pupal cell that the inactive pupa will not be crowded and eventually smothered by the penetration of roots into the cell, which would undoubtedly take place near the surface of the soil in a field. Grubs in the tin boxes showed no discomfort at being prevented from penetrating to a depth in the soil.

The freshly issued adult (Pl. IV, fig. 6) was left in the pupal cell in the box for several days, to observe its changes in color in reaching maturity. In a week's time or less, before the beetle had shown a desire to leave the cell, a round disc of blotting paper was snugly fitted into the box over the earth and cell, and the box was buried, with lid removed, under several inches of damp earth in a jar or pot, the earth packed somewhat, and a cover or cage put over the top in order to determine the date of emergence from the soil.

Species of Porto Rican Melolonthids.

All five species of Porto Rican Melolonthids that have been segregated and studied are new to science. The four indigenous species of *Phyllophaga*, or May-beetles, are being described by the author under the names *Phyllophaga vandinei, P. portoricensis, P. guanicana* and *P. citri*, and the single species of *Phytalus* under the name *Phytalus insularis*.

The characters which distinguish the species are sufficiently marked to readily separate them from allied species occurring on the neighboring islands. In the present paper will be given only the more important characters necessary to distinguish one species from the other.

As the four species of *Phyllophaga* fall naturally into two groups, readily distinguishable by size and other gross characters, and as the two species of each group are restricted to well-defined geographic areas on the Island, one can almost with certainty determine the species by the locality in which it was collected, knowing the appearance of each group. The males of the four species can be separated by the characters shown in figures 4, 5, 6 and 7, of Plate V.

which illustrate the male genetalia viewed from the left side. The characters of the female genetalia are less well defined in the two species of either group, but those of the two groups are quite distinct in appearance, as is shown by figures 8 and 10, Plate V, representing one species of each group.

The species *Phytalus insularis* conforms with the described character separating the genus from *Phyllophaga*. This consists in the tooth of the tarsal claw being situated near the end of the claw, and directed at an acute angle instead of at an obtuse or right angle to it, making the claw what is termed "cleft." This character is more or less variable with other species of *Phytalus*, but holds good in the case of *P. insularis* and *P. smithi* Ar.

A notworthy fact is that all of the Porto Rican Melolonthids, including *Phytalus*, in common with the species from neighboring islands, possess certain marked characters not ocurring in the species from the mainland which have been examined. This would seem to set them apart as belonging to another genus. These characters consist in: (1) the presence, on the inner posterior angle of the femora of the hind pairs of legs, of a longitudinal row of prominent, stout, rather blunt spines, varying usually from three to five in number, and below each spine a long bristle—where in the species of the continent this angle is bare of spines and has few, if any, bristles; (2) the constriction of the transverse, sub-median ridge on the outer face of the back tibiae, which in American continental species is directed downward and bears a prominent row of bristles, or slender spines, into an anterior and a posterior flattened spur, the former bearing from three to five bristles and the latter from one to four bristles; and (3) in the presence, above the posterior flattened spur and less than midway between it and the base of tibia, of another flattened spur, bearing from one to three bristles—which in continental species is indicated, if at all, by no more than a slight elevation above a pit bearing one bristle. Occasionally, in Insular species, there is a third flattened spur above this last, having one to two bristles.

These characters of the rear tibiae occur in the West Indian species of *Phytalus* as well as in *Phyllophaga*, and make it appear that the West Indian species of *Phyllophaga* are a link between *Phytalus* and the *Phyllophaga* of North America.

CHARACTERS IN THE GENITALIA.

It is well known that many species of *Phyllophaga* of the American continent are practically indistinguishable from external char-

acters, and that it is necessary to extract and examine the genitalia in order to separate them. The same is true of Porto Rican species, especially as regards closely related species in either group. Of the two sexes, the genitalia of the male are the more highly specialized, and therefore of greater use in separating species.

The genitalia of a male *Phyllophaga* may be described as a semi-chitinous, tubular, protractile organ whose distal end, for about one-third of the entire length, is enlarged and modified into a collar, or theca, which is parted longitudinally on the ventral side. The theca is articulated at the sides to the upper or proximal portion of the genital organ, the dorsal suture being protected by a tympanum. The distal margin of the theca is nearly circular and cuplike, concealing the fleshy phallus; the ancipital margins on the ventral side are variously modified into corneous hooks or barbs. In many American species of *Phyllophaga*, including such species as *hornii, ilicis* and *bipartita*, the theca is greatly modified, becoming articulated on the dorsal side and formed into two highly specialized claspers, which are dissimilar in shape. In other species, such as *quercus, rubiginosa* and *forbesi,* the theca is bilaterally symmetrical and more regular in shape, as is the case with Porto Rican species. In none of the American species, however, is the phallus (which may be known as the median lobe of the genital organ) highly specialized as in the species of the Island.

The median lobe of the male genitalia of Porto Rican species bears, normally, a superior, deflexed, acicular process, or spicula, which is roundly bent toward the right, and an inferior pair of adnate, falciform armatures, which cross scissor-like at their bases and re-cross, or at least meet, at their tips. (See Pl. V, figs. 6 and 7.) In the group including the two species of smaller size (*guanicana* and *citri*) the adnate armatures are fused into a single spatha, which is in one case fleshy (*guanicana*) and in the other case chitinous (*citri*). In the group including the two larger species (*vandinei* and *portoricensis*) the adnate armatures are distinct, chitinous, dark brown and shining, the dextral armature superior and the sinistral inferior; they are compressed or cylindrical at their bases and depressed at the tips, which lie one over the other. The distinguishing characters lie in the structure of the tips of these armatures, which are bicuspidate in one (*vandinei*) and spatulate in the other (*portoricensis*).

The female genitalia consist, in American species, of two pairs of flattened plates, an inferior and a superior, the latter extending beyond the former, and above the superior plates, at their suture, a

pubic process of varying form, which is often lacking or concealed. The inferior and superior plates are often fused together. Among Porto Rican species this seems to be the case, and the pubic process is visible only in species of the larger group (*vandinei* and *portoricensis*).

The following key will serve to separate readily the five Porto Rican *Melolonthides:*

KEY TO PORTO RICAN MELOLONTHIDES.

A. Theca of male genitalia cyanthiforn, closed ventrally. *Phytalus.*

B. Theca of male genitalia collar-shaped, open ventrally. *Phyllophaga.*

- *a.* Adnate armatures distinct and chitinous; spicula medial; female genitalia with prominent pubic process. (Group of larger species.)
  - I. Armatures bicuspidate at tip; spicula sharply deflexed. *P. vandinei.*
  - II. Armatures spatulate at tip; spicula roundly deflexed. *P. portoricensis.*
- *b.* Adnate armatures fused into a single spatha; spicula dextral: female genitalia without pubic process. (Group of smaller species.)
  - III. Spatha fleshy, surmounted by minute prostrate spinules. *P. guanicana.*
  - IV. Spatha cymbiform, chitinous and polished above. *P. citri.*

Phyllophaga vandinei n. sp.[1]

This species has been named for Mr. D. L. Van Dine, the first entomologist of the Experiment Station of the Porto Rico Sugar Growers' Association, who, by reason of his characteristic zeal and energy, was largely responsible for the extensive importations of white-grub parasites and for instigating the work carried on with the sugar-cane white-grubs of the Island in the past five years.

The larva of this species is the worst sugar-cane pest of the Island, and is perhaps one of the three most injurious sugar-cane white-grubs in the world. Its habitat on the Island is restricted to the western end, its farthest east recorded occurrence being at Manatí on the north coast and at Peñuelas on the south. Within this limited territory it has reached, particularly in the Guánica district, such great abundance as to often have caused whole fields of cane to fall prone and to begin to sour in a week's time after damage first became evident. It has made the growing of ratoon cane in the Guánica and San Germán districts impossible, and in addition to the cost of replanting for each crop, has levied a tax upon the centrals for the continued hiring of boys to collect the grubs and beetles that amounts to hundreds of dollars in a single season.

[1] Technical description of this and the other species will be published later.

Cases are on record where over fifty grubs of this species have been spaded out from under a single stool of cane. It is no uncommon occurrence to dig out twenty or more grubs from one cane stool. So prolific is the species that it requires constant vigilance on the part of the sugar centrals of the infested district to keep the insect in check. Boys are paid at a regular rate per quart for beetles collected on the cane foliage by lantern at night, and women are paid by the quart for grubs collected in the plowed fields in the daytime. By these means hundreds of bushels of beetles (see Pl. II, fig. 4) and grubs are collected every season and destroyed, or fed to hogs.

Some idea of the cost of this propaganda may be derived from the following figures, available through the courtesy of the general manager of Guánica Centrale, where accurate records of the daily collections of grubs and beetles are kept:

In seven months of 1914 during which collections of beetles were made (February 27 to September 23), the total collections in five *haciendas* belonging to Guánica Centrale amounted to 2,255,000 beetles, gathered at a total cost of $833.87.

The collections of grubs for six months of the same year (from November 27, 1913, to May 14, 1914) amounted to a total of 1,662,000 grubs, gathered at a cost of $1,876.73.

In six months of the following year (March 6 to September 9, 1915), on the same *haciendas* of Guánica Centrale, the collections of beetles amounted to a total of 2,468,000, gathered at a cost of $1,425.20.

The number of grubs collected in seven months of 1914 and 1915 (from October 29 to May 27) amounted to a total of 2,425,000, gathered at a cost to the central of $2,018.57.

Figuring 400 beetles to the quart, and 300 grubs to the quart, this makes the rather startling figure of 369 bushels of beetles and 426 bushels of grubs collected in two years from a small district by one sugar central, at a total cost of $6,154.37.

And still this beetle is not held in check, but appears to continue to increase in abundance. It is small wonder that the sugar-cane growers of Porto Rico have become exercised over the depredations of the "gusano blanco," as the white-grub is known locally.

THE BEETLE.

The adult of *Phyllophaga vandinei* is a May-beetle of normal appearance, smooth and faintly shining in both sexes, but not pol-

ished, tawny to chestnut brown in color, and varying from 17 to 22 mm. in length. (See Pl. IV, fig. 3.) From *P. guanicana* or *P. citri* it is at once separable by its larger size, lighter color and smoother surface. From *P. portoricensis* it is distinct in being confined to a different habitat, as well as by the characters cited in the preceding table.

Unlike most species of *Phyllophaga, vandinei* may be found in some abundance in the fields throughout at least eight and often nine months of the year. In the Guánica district, where it has been closely studied, it makes its first appearance during the last days of February, and by the last of March is abundant, remaining so from then up until late in September or the middle of October, when it rapidly decreases in numbers; and by the second week of November few are to be found in the fields. During the two years of 1914 and 1915, figures compiled by Guánica Centrale show that the beetles were most abundant in 1914 from the last of July to early in September, while in 1915 they were most plentiful from the middle of April to early in July. These variations may be due to climatic conditions in individual seasons.

As the life-cycle of the species covers only one year, or a period of ten months for the actual egg-to-adult cycle, and as there is a possible variation (as shown by breeding experiments) in this cycle ranging from seven to thirteen months, it is evident that there must occur an overlapping of broods, to such an extent, in fact, as to distribute the emergence of adults over all of the summer months.

THE LIFE-HISTORY WORK.

As this species is the worst cane pest of the Island, and the ultimate object of all the experimental work on white-grubs was to find a practical method of controlling it, the laboratory-insectary erected for its study, and called the South Coast Laboratory, was located at Santa Rita, midway between Guánica and Yauco, in the heart of the district worst infested by this beetle. Most of the white-grub work was put upon the one species, with the result that its habits and life-history are better known than those of any other species occurring on the Island.

More than twenty individuals of *Phillophaga vandinei* were reared from egg to adult, and twice as many more were reared successfully to the pupal stage. Many hundreds of eggs from confined adults were kept under observation, and the grubs hatching from them were fed and regularly observed; but a majority of these died

before reaching maturity, some from disease or from the artificial conditions of their confinement, others from wrong handling through ignorance of the essentials for their growth. The total number of eggs, larvæ, and pupæ of this species whose molts and instars were recorded was as follows: Eggs, 1,502; grubs in first instar, 852; grubs in second instar, 209; grubs in third instar, 117; pupæ, 46.

The two charts on Plate VIII show in graphic form the length of the egg to adult period of *Phyllophaga vandinei.*

LENGTH OF LIFE-CYCLE.

The life-cycle of *Phyllophaga vandinei* covers, roughly speaking, one year. The average normal egg-to-adult period covers just ten months. The average from fourteen complete records of single individuals run from egg to adult was 306 days; the average obtained by adding together the average lengths of the three immature stages—the egg, three instars of larva, and the pupa—was 302 days. The disparity is easily accounted for.

The maximum egg to adult period of the fourteen individuals was 395 days; the minimum, 212 days. Or in terms of months, they were, respectively, 13 and 7 months.

Observation has shown that the adult beetle, after issuing from the pupa, may remain in the soil in the pupal cell for a period varying from two weeks to perhaps two months. The period of pre-oviposition of adults was not experimentally determined, because of the refusal of reared specimens to oviposit, and the difficulty of being sure whether specimens collected in the field had just emerged or not. Calculating the pre-emergence period to average a month, and the pre-oviposition period to require close to a month, the species is seen to have a life-cycle of virtually one year.

The possible shortening or lengthening of the egg-to-adult period by three months, which was demonstrated in rearing boxes, and which would shorten or lengthen the entire life-cycle by an equal period, gives the life-cycle of the species a proven variation of nine to fifteen months. This might be still further lengthened by the fact that the egg-laying period of the female may extend over a period of more than a month.

It is very conceivable that an egg laid quite late in the fall might not, under adverse conditions, emerge as an adult until the spring of the second year following; or on the other hand, that an egg laid in spring might, under very favorable conditions, produce an adult in the fall of the same year. This last, in fact, happened in one of

the rearing boxes (see Plate VIII, No. 1211*a*), although there is no way of knowing whether the adult would have emerged from the ground in the fall, under natural conditions, or would have remained in the pupal cell until the following February or March. All of which readily explains the occurrence of adults in the cane fields throughout most of the year.

THE EGG STAGE.

The average length of the egg stage, from the date it is laid to the date of hatching, was determined as fourteen days. This average was secured from a total of 1,089 eggs, the hatching of which was observed. The maximum length of egg stage was seventeen days, recorded in March, and the minimum ten days, recorded in September.

Description.—The egg of *Phyllophaga vandinei* is opaque and pearly white in color (in that regard resembling the eggs of other species of the genus). When first laid it is slender oblong-oval in shape, about 2.75 mm. to 3 mm. in length by 1.62 mm. to 1.75 mm. in breadth. It swells greatly before hatching, and becomes almost spherical, 3 mm. to 3.25 mm. in length by 2.35 mm. to 2.65 mm. in breadth. (See Plate III, fig. 1.)

Eggs are deposited among roots in the soil in small globular pits, or cavities, which are made by the ovipositor of the female. One egg is laid in each pit and rests at the bottom. (See Plate V. fig. 9.) The earth forming the walls of the pit is cemented or compressed in such a way that even in dry sifted soil the pits usually remain intact, when the soil is sifted, until put under pressure of the thumb. The pit varies from two to three times the diameter of the egg, and serves to maintain a uniform humidity as well as to prevent the soil from touching the egg. When fully swollen the egg does not completely fill the pit, so that when it hatches the grub, which is half again greater in diameter than the swollen egg (see Plate III, fig. 2), has a natural cell in which to move about and begin existence.

THE WHITE-GRUB, OR LARVAL STAGE.

In common with other white-grubs, the larva of *Phyllophaga vandinei* molts its skin three times, passing through three distinct instars. In computing the length of life-cycle the average, maximum, and minimum lengths of each instar were found.

Of fifty larvæ of this species reared from egg to pupal stage, in which the exact dates of hatching of egg and of pupation were re-

corded. the average length of larval stage was 267 days: the maximum. 356 days: the minimum. 179 days. Or, reduced to months. the average length of larval stage was about nine months: the maximum. twelve months: and the minimum. six months. It is at once apparent that the astonishing variation in the length of life-cycle of this species is due to the variation in length of the larval. or grub. stage. the egg and pupal stages showing very little variation in duration. (See charts on Plate VIII.)

Nine out of ten months (or 90 per cent) of the insect's normal life below ground are spent in the larval. or grub. stage. During most of this time the grub is doing actual damage to cane by feeding upon the roots.

The length of larval period. secured by adding together the averages of the three instars. amounts to 266 days. This constitutes a very good check on the above average of 267 days. computed from the whole larval stage of 50 larvæ. since a good many of the grubs from which the instar averages were taken never reached pupation. and conversely. a majority of the grubs whose exact dates of egg hatching and of pupation were recorded. were not observed and recorded as to their molts: so that the two results were taken to a large extent from different series of grubs.

The explanation for fifty grubs having reached the pupal stage. whereas only about twenty reached the adult. lies in the fact that at the time of pupation the grub is particularly susceptible to injury by handling. or by attack of the bacterial disease. *Micrococcus nigrofaciens* Nor. (17). Many grubs while active seemed to resist the disease. which attacked a majority of them. but during the quiescent prepupal stage they succumbed. The presence of mites on the body of a grub would often prevent its pupation. or cause the pupa to be deformed. and the adult would not issue.

The first instar.—Technical descriptions of this and the other instars and stages of *Phyllophaga vandinei* will be given in a later issue of the Journal. when detailed studies have been completed. For the present. the plates may be depended upon to give a fairly accurate impression of the size and appearance of the different instars of the grub.

The average duration of the first instar was determined as 36 days: the maximum. 59 days (in December): the minimum. 17 days (in June). The maximum duration was found to be more than three times the minimum. The duration of this. as well as the other instars of the grub. has been shown to be influenced more by the amount of moisture in the soil. and by the presence or absence of mites. fun-

gus or bacterial disease, than by the amount of food provided the grub. (When grubs succumbed to the *Metarrhizium* fungus during the second or third instars, it was found that the earlier instars had been above normal in length.)

From the fact that larvæ of May-beetles are always in a coiled position, and seldom straighten out to crawl as do the grubs of Rutelids and Dynastids, it is very difficult to measure their length. It was ascertained, however, that the length is just double the measurement across the coiled body, so that the length of grubs in the various instars was determined in this way.

At the time of hatching from the egg, the grub of *vandinei* is about 6 mm. long and 1.75 mm. to 1.8 mm. across the head. Before molting to the second instar (see Plate III, fig. 3) it reaches a length of 17 mm. to 18 mm., and the head reaches a diameter of 1.9 mm. to 2 mm. (Pl. V, fig. 1.)

The head does not grow like the body, but that it enlarges somewhat in size may be shown by the following brief table, from actual measurements with sliding calipers from living grubs:[1]

HEAD OF FIRST-INSTAR GRUBS.

An average from 5 grubs varying from 5 to 10 mm. in length; head 1.85 mm. wide.

An average from 29 grubs varying from 11 to 15 mm. in length; head 1.96 mm. wide.

An average from 11 grubs varying from 16 to 18 mm. in length; head 2.01 mm. wide.

During the first instar no damage is done by the grub of *vandinei*, since it lives entirely upon vegetable matter in the soil. It is only during the very last days of the instar, or more commonly in the early part of the second instar, that the grub begins to eat living roots.

The second instar.—The average duration of the second instar (see Plate III, fig. 4) was found to be 47 days; the maximum, 103 days; the minimum, 26 days. Or, reduced to months, the average was one and one-half months; the maximum, three and one-third months; and the minimum, somewhat under one month. It is seen that the maximum duration of this instar was more than four times the minimum.

At beginning of the second instar the length of the grub is 17 mm. to 18 mm.; at end of the instar, and just before molting to the third instar, the length is 28 mm. to 30 mm. The average width of head, taken from 43 second instar grubs, was 3.33 mm. (See Plate V, fig. 2.)

[1] NOTE.—Measurements of small objects made with sliding calipers are very apt to average from .1 mm. to .15 mm. above actual size.

An idea of the enlargement in the head during the second instar may be gained by the following figures, taken from measurements of living grubs:

HEAD OF SECOND-INSTAR GRUBS.

An average from 23 grubs varying from 18 to 25 mm. in length; head 3.25 mm. wide.

An average from 20 grubs varying from 26 to 30 mm. in length; head 3.42 mm. wide.

The third instar.—The average duration of the third instar, from records of 25 grubs, was found to be 183 days; the maximum 266 days; the minimum, 78 days. Again, the maximum duration of the instar is more than three times the minimum. Reduced to months, the average length of the third instar is six months; the maximum, nine months; and the minimum, two and one-half months.

Approximately two-thirds of the larval period is spent in the third or last instar, or about three-fifths of the entire life of the immature insect. During more than six months of the year this insect is doing great injury to crops in the soil as a grub. There being no winter in Porto Rico during which the grub is not feeding, its activity as a root trimmer extends not only through five and one-half months of the third instar (allowing one-half month for the quiescent, pre-pupal stage), but also through the month and a half of the second instar, so that the period of injury may easily cover seven months.

At beginning of the third instar (see Plate III, fig. 6) the grub averages about 28 mm. in length, and when full grown (see Plate III, fig. 7) it reaches a length of 40 mm. to 44 mm. The average width of head from 96 grubs measured in the third instar was 5.29 mm. (See Plate V, fig. 3.)

The rate of growth of the head during this instar may be seen from the following table:

HEAD OF THIRD-INSTAR GRUBS.

Average from 30 grubs varying from 26 to 30 mm. long; head 5.13 mm.
Average from 19 grubs varying from 31 to 35 mm. long; head 5.26 mm.
Average from 42 grubs varying from 36 to 40 mm. long; head 5.39 mm.
Average from 5 grubs varying from 41 to 45 mm. long; head 5.45 mm.

The factors which influence the rate of growth in the third instar of the grub are:

(1) Available food supply; *i. e.*, contiguity of abundant living plant roots.

(2) Humidity and texture of soil. Hardness or softness of the

soil naturally retards or facilitates the easy movements of the grub in its constant search for fresh roots. For this reason white-grubs are worse pest in friable than in heavy clay soils.

(3) Temperature (time of year). The length of this instar somewhat increases, as do the others, during the winter months, though at no time of year do the grub's activities entirely cease as result of cold weather, as happens in more northern latitudes.

(4) The presence of disease in the grub. As previously stated, infection with the *Metarrhizium* fungus greatly retards the activity and growth of the grub, as does bacterial infection, thus lengthening the duration of the instar.

(5) Attack by mites, or by other dermal parasites that molest the grub.

THE PRE-PUPAL STAGE.

The so-called pre-pupal stage of white-grubs is the resting period that occurs at the end of the third instar during which the grub is preparing for pupation. It is characterized by a puckering or gathering of the skin, general flabbiness, and a discoloration or yellowing in color (see Plate III, fig. 8). The larva lies on its back, dormant, in a rounded, oblong cell about 35 to 40 mm. long; the body is much flattened and the caudal end rather sharply bent upward; the legs are held stiffly outward, close together, and display little or no movement. There is no molt between the third instar and the pre-pupal stage.

From two weeks to a month prior to the pre-pupal stage, the grub shows the approach to pupation by its sluggishness, by the body becoming yellow, more opaque, and harder to the touch, and by a disappearance of the dark stain at the caudal end of the body resulting from the earthy excretious matter within.

From about a dozen observations of reared grubs, the pre-pupal stage varied from four to seven days. There was in each case an added period of about a week to two weeks during which the grub was sluggish and did not feed, thus indicating its preparation for the pre-pupa.

THE PUPAL STAGE.

When the pre-pupa molts, the pupa is at first white and misshapen; but within twenty-four hours it has assumed its natural shape (see Plate III, fig. 9; also Plate IV, figs. 1 and 2) and shining yellow-brown color. The pupa lies on its back in the cell, and the

crumpled molt skin (Plate III, fig. 9) remains near it, at the caudal end.

The average duration of the pupal stage, from 22 observations, was $21\frac{1}{2}$ days; the maximum, 26 days; the minimum, 17 days.

From thirteen measurements, the average length of the pupa was 25.1 mm., the average width 11.15 mm., and the average breadth of the head 8.18 mm.

A day or two before hatching into the adult, the pupa turns over in its cell and lies with the back upward. In this position the adult is always found in the cell, never with back downward. On a pupa about to hatch the skin is wrinkled, and the white color of the elytra may be seen through elytral sheaths. (See Plate III, fig. 10.) The formation and sculpture of the legs may also be seen through the now transparent pupal skin.

ISSUING AND EMERGENCE OF ADULT.

An adult just issued has only the legs, head, and thorax brown, the elytra being white and soft, and the wings extended their full length beneath the elytra. (See Plate IV, fig. 6.) In a few hours the beetle turns tawny yellow in color, then gradually deepens in shade during the following week.

The term issuing applies to the breaking of the pupal skin, and the exit of the newly formed adult from the pupa; the term emergence applies to the appearance of the beetle above ground. The interim between these two periods is spoken of as the period of pre-emergence, and is the time spent by the newly-hatched beetle in the pupal cavity in the soil—a time very necessary for the chitinous parts of the beetle to become perfectly hard, so that it can dig its way upward to the surface of the ground.

In many North American May-beetles the pre-emergence of adults covers a period of several months—usually from the late summer or fall of one year to the spring of the next. In the Porto Rican species this period extends rarely over five to six weeks, judging from observations.

Because of the fact that most of the confined specimens of *vandinei* were reared in small tin boxes, in which the adults at time of pre-emergence were disturbed and did not behave normally, our records of pre-emergence are somewhat incomplete. The following notes, however, prove it to extend over a period of two weeks or more:

(1) *No. 547.*—On July 1 two adults hatched from pupae in earth in a jar,

which were still alive in the cells but had not come to the surface of ground when the soil was dumped, July 30. Time, over 29 days.

(2) *No 548.*—One female and two male adults, hatched in a battery jar on July 3, 7 and 18, respectively, had not reached surface by July 30, though two of them were still living. Time, over 12 to 27 days.

(3) *No. 1172c.*—A female, issued April 12 in a jar, had not come to the surface on April 28, though still living. Time, over 16 days.

(4) *No. 1219b.*—A female hatched February 15 and had not come to surface through four inches of damp soil by March 10, though still alive. Time of pre-emergence, over 23 days.

DISTRIBUTION OF THE SPECIES.

Phyllophaga vandinei is confined to the western end of the Island, a territory equivalent to about one-third of the area of the Island. Its eastern distribution may be defined, roughly, so far as our present knowledge goes, by a north and south line across the Island through the towns of Manatí on the north and Peñuelas on the south. The type of the species is from Santa Rita, near Guánica.

The analogue of this species at the eastern end of the Island is *Phyllophaga portoricensis,* which is indistinguishable from the former species except by means of the genital characters given in the table. It is indeed possible that the two are but races of one species, for there seems to be a general intergrading of the characters along the geographic line separating the two species. Yet at no time have the two been taken in one locality; and the specific characters are sufficiently recognizable in specimens from the type localities, Guánica and Río Piedras, to set apart the species as quite distinct.

FEEDING HABITS OF THE ADULTS.

All May-beetles feed upon the foliage of plants and trees, and are voracious eaters. The adult of *vandinei* differs from many species of the genus in being a very general feeder, and there are few plants which it will not touch. Feeding is done entirely at night, the adults issuing from the ground at dark, or a little before. After a very brief flight, they alight upon suitable foliage and begin to feed upon the margins of the leaves. Feeding continues until very late into the night, the beetles appearing to be as abundant after midnight as before. Spending thus six hours or more of the night in feeding, they consume quantities of vegetation. Small tress of ''quenepa,'' of ''salcilla,'' and of native china-berry have been found completely stripped of foliage by this species. Cane also suffers from depredations of the adults, but not to such an extent as the foliage of certain trees. A common ornamental tree of the south side of the

Island, the casuarina, and another of general use along roads in Porto Rico, the flamboyant, are both very badly attacked by adults of this species. Banana and coconut trees often show acute injury from their feeding. (See Plate I, figs. 1 and 2.)

It has not yet been determined at what hour of the night their feeding terminates, but it must be well toward morning, as they have been collected feeding as late as 2 a. m. Nor is it known whether, at termination of feeding, they fly or drop to the ground. When disturbed in feeding they drop, using the wings usually to carry them a short distance; and this is probably the method employed at the end of the feeding.

So uniformly abundant is *Phyllophaga vandinei* over the infested area that unusual and sporadic appearance of adults in such numbers as to cause bad defoliation in restricted areas is rare. The infestation is general, and usually heavy. Cane foliage may always be found somewhat damaged in the Guánica district and the San Germán valley.

Following is a list of some of the commoner plants and trees occurring in or near cane fields in the infested area, grouped according to their attractiveness to the beetles.

(1) Those greatly relished by the adults—

Flamboyant (*Poinciana regia*); Australian pine (*Casuarina equisetifolia*); almendro (*Terminalia catappa*); salcilla (*Schrankia portoricensis*); quenepa (*Melicocca bijuga*); guasima (*Guazuma guazuma*); China-berry (*Melia azedarach*); tamarind (*Tamarindus indicus*); jobo (*Spondias lutea*); banana (*Musa* sp.); coconut (*Cocos nucifera*); cecropia (*Cecropia palmata*); pig-weed, or bledo (*Amaranthus* spp.); mallow (*Malachra rotundifolia*); and *Petiveria alliacea*.

(2) Those eaten to some extent, but not apparently as much relished as trees and plants in the preceding list—

Sugar cane (*Saccharum officinarum*); guava (*Psidium guajava*); almacigo (*Bursera simaruba*); jaguey (*Ficus lentiginosa*; bucago (*Erythrina glauca*); royal palm (*Roystonea borinquena*); eucalyptus (*Eucalyptus* spp.) (very rarely); Jamaican sorrel (*Hibiscus sabdariffa*); native cotton (*Gossypium* sp.); Guinea grass (*Panicum maximum*); malojillo, or Para grass (*Panicum barbinode*); *Casearia sylvestris;* and *Cordia corymbosa.*

(3) Those which appear to be entirely exempt from attack by the adults—

Hawaiian algarroba (*Prosopis juliflora*); papaya (*Carica papaya*); gallito (*Sesbania grandiflora*); gandul (*Cajanus indicus*); pepper tree (*Schinus molle*); black sage (*Cordia cylindrostacha*); roble (*Tabebuia rigida*); calabash (*Crescentia cujute*); berengena cimarrona (*Solanum torvum*); silk cotton weed (*Calotropis procera*); acalypha (*Acalypha wilkesiana*); *Citrus* spp.; and *Clidemia* spp.

HABITS OF FLIGHT.

During the day the beetles conceal themselves by burrowing into the ground, usually near the bases of trees or large weeds. Often a dozen or more holes may be found around the base of a tree upon which they have been feeding. At night they begin issuing from these burrows at about sundown, and their flight seldom lasts for more than fifteen to twenty minutes.

On one occasión, in October, observations were made at sundown of a large screened cage into which had been put five hundred adults a few evenings before. The beetles began appearing from the soil at 6:25 p. m., were issuing in greatest numbers at about 6:35 p. m., and had practically ceased to appear by 6:45 p. m. The majority took wing immediately upon making their exit from the holes, or crawled up a near-by weed and then took wing; a few climbed weeds and began to feed without flying at all. Nearly all flew westwardly, against the western side of the cage. The flight of the majority lasted until about 6:50 p. m.; the last of them had ceased flying by 7:00.

Adults of this species do not usually fly for long distances. By watching up and down a "callejón" (a bare or grass alleyway 20 to 30 feet wide) between cane fields at about dusk, in a place where infestation by the beetles was known to be heavy, it has been noted that comparatively few of the beetles flew across the "callejón," but that the majority hovered over the cane plants very near to where they had arisen. On various occasions casuarina trees in a Bermuda-grass lawn were watched at dusk, and it was noted that the beetles usually hovered around the trees near whose bases they had made exit from the ground, but never arose high and took direct flight for more distant trees.

Another observation confirmed the belief that the dispersion of *vandinei* by flight is not extensive. In a large outdoor screened experimental cage, 6 by 10 feet in area, into which 2,000 beetles were introduced on April 2, it was observed a week later that the cane growing at the end of the cage where the beetles had been introduced was entirely stripped of foliage, while cane growing at the opposite end was virtually untouched, showing decidedly the slow dispersion by flight.

ATTRACTION TO LIGHT.

Adults of *vandinei* are quite readily attracted to light, as is usual with May-beetles. Experiments were made with a large 500–c. p.

Pitner gasoline lamp, with a view of finding some suitable method of taking advantage of this fact for the destruction of the beetles. The lamp was placed on the roof of a two-story building near the insectary at Santa Rita, and a canvas stretched on a vertical frame was put beneath the light. Since a few individuals often come to an ordinary lamp in a room, it was expected that the Pitner light, with its great power, would attract large numbers. This hope was not justified, as out of twenty-three evenings in July, August, October, and November during which the light was run, beetles were taken on only seven, a total of twenty-four being taken.

The reason for this scarcity of beetles was that the Pitner light was always started about 8 o'clock, and *Phyllophaga* adults are ordinarily only attracted to light during their flight and before they have settled on foliage to feed (before 7:30 p. m.). To have any practical efficiency in attracting *vandinei* adults for destruction, a light must be close to the ground, and must be started immediately at dusk, while beetles are flying. It need not be run for over an hour after dark, as time after that is wasted. There have been cases where adults of this species and *portoricensis* have left their feeding on the foliage and flown to a motorcycle headlight as late as midnight or after, but these cases are rare. Almost never, while collecting beetles with a bull's-eye light, have they been known to leave their feeding and fly to the light.

COPULATION.

This species is not often found in copulation in the field, the reason being that collecting is usually done after 8 p. m., while mating takes place before that hour. On one occasion recorded, when collecting was done between 6:45 and 8:25 p. m. (on October 14), out of 79 adults collected on cane, "salcilla" and "malojillo," only one pair was found in copula (at 7 p. m.). Lateness of the season may have accounted for so few being found copulating at that hour.

Pairs were occasionally found copulating on the foliage of small casuarina tress near the insectary. Pairs thus observed on two evenings in April were recorded as follows:

(1) Copulation began before 7:30; ended at 7:45; duration 15 minutes +.
(2) Copulation began before 7:30; ended at 7:53; duration 23 minutes +.
(3) Copulation began before 7:35; ended at 7:45; duration 10 minutes +.
(4) Copulation began before 7:35; ended at 7:48; duration 13 minutes +.
(5) Copulation began before 7:35; ended at 7:50; duration 15 minutes +.
(6) Copulation began before 7:35; ended at 7:50; duration 15 minutes +.
(7) Copulation began at 7:31; ended at 7:52; duration 21 minutes.
(8) Copulation began at 7:34; ended at 7:53; duration 19 minutes.

It is evident that copulation of this species takes place quite uniformly between 7 and 8 p. m., or immediately after the cessation of flight, and that the average duration exceeds sixteen minutes. It may possibly be learned, with further observation, that the oviposition of the Tachinid parasites, *Cryptomeigenia aurifacies* Wal. and *Eutrixoides jonesii* Wal., on the adult beetles takes place during the copulation and before the total darkness of night comes on.

OVIPOSITION OF FEMALES.

Oviposition takes place in the soil adjoining the beetle burrows at the bases of trees and plants, where the young larvæ will be immediately among the roots. Exact depth at which eggs are laid in the soil has not been determined, but probably averages from eight inches to a foot, the depth at which beetles are usually found in their burrows.

As stated before, to secure eggs in confinement for the purpose of determining the length of the period of oviposition of females and the average number of eggs laid by a female, beetles were confined both singly and "en masse;" and the results from the two methods did not vary much. The method of confining the females has been described on page 63. No eggs were secured from reared females, unfortunately.

The individual egg-laying records of females of *vandinei* are graphically shown in the two charts on Plate IX. The complete records are given in the following tables:

Egg-Laying Records of Individual Females of Phyllophaga Vandinei n. sp.

Exp. Number	Date	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Lived Days	Laid Eggs	Eggs per Day
1192 *	3- 8	2	0	3	0	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5— 8	0	.000
" *	3-23	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1— 3	0	.000
1206	3- 3	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	0	3	0	3	0	3	0	4	0	8	0	5	0	...	...	...	...	...	...	56—61	0	.000
1207	"	7	5	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	23	3	0	3	0	3	0	4	0	...	...	...	...	...	...	...	...	...	...	41—48	28	.609
1208	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	21	3	0	3	0	3	0	4	0	8	10	5	0	4	0	3	0	3	0	68—71	31	.446
1209	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	0	3	0	3	0	3	0	4	0	8	0	5	0	4	35	3	0	3	0	68—71	35	.501
1210	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	27	3	0	3	0	3	0	4	0	8	0	5	0	4	0	6	0	5	12	71—76	39	.531
1211	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	10	3	0	3	0	3	1	4	8	...	...	...	...	...	...	...	...	...	...	44—48	19	.413
1212	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	0	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	35—38	0	.000
1213	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	20	3	0	3	6	3	0	4	9	8	10	5	0	4	0	3	0	3	0	68—71	45	.617
1214	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	23	3	0	3	0	3	0	4	0	8	6	5	0	4	0	6	0	9	0	76—80	29	.372
1215	"	7	9	3	0	3	0	3	0	4	0	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20—23	9	.419
1216	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	14	3	0	3	0	3	0	4	2	8	11	5	2	4	0	...	...	...	...	61— 65	32	.508
1217	"	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	20	3	0	3	0	3	0	4	11	8	1	...	...	...	...	...	...	...	...	48 -56	32	.615
1218	3-24	...	...	...	...	...	...	...	...	...	...	2	0	3	0	3	0	6	0	3	0	3	0	3	0	4	0	8	29	5	5	4	0	6	0	5	0	49—54	34	.660
1219	3- 3	7	0	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	30	3	0	3	5	3	0	4	0	8	6	...	...	...	...	...	...	...	...	48--56	41	.788
14 *	Total	7	14	3	0	3	0	3	0	4	0	3	0	3	0	3	0	6	188	3	0	3	11	3	1	4	30	8	76	5	7	4	35	4½	0	4½	12	Average 56.21	Total 374	Aver .165
1233 *	3-15	4	0	4	0	3	0	3	0	3	0	6	0	3	0	3	0	3	0	4	0	8	0	5	0	4	0	...	...	...	...	...	...	...	...	...	...	49—53	0	.000
1234	5- 7	3	0	3	0	5	3	16	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11—27	4	.211
1261 *	4- 8	2	0	3	0	3	0	4	0	8	0	5	0	4	0	3	0	3	0	5	0	8	0	13	0	...	...	...	...	...	...	...	...	...	...	...	...	18—61	0	.000
1262	"	2	0	3	0	3	0	4	0	8	0	5	0	4	0	3	0	3	0	5	0	8	7	13	0	8	0	...	...	...	...	...	...	...	...	...	...	61—69	7	.108
1270	4-12	4	0	4	0	13	0	4	0	3	0	3	0	5	0	8	0	13	6	8	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	57—65	7	.115
1271	"	4	0	4	0	13	0	4	0	3	0	3	0	5	0	8	0	13	0	8	0	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	65—78	0	.000
1272	"	4	0	4	0	13	0	4	0	3	0	3	0	5	0	8	0	13	0	8	0	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	65—78	0	.000
1281 *	4-28	1	0	4	0	4	0	3	0	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	12—15	0	.000
1281 a	4-20	7	0	7	0	3	0	3	0	3	0	5	18	6	0	15	0	8	2	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	57—65	20	.328
" b	"	7	0	7	0	3	0	3	1	3	0	5	10	6	0	15	8	8	0	8	0	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	65 69	19	.284
" c	"	7	0	7	0	3	0	3	0	3	0	5	13	6	0	15	11	8	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	49—57	26	.490
" d	"	7	2	7	0	3	0	3	0	3	0	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	23—28	2	.078
" e	"	7	0	7	0	3	0	3	0	3	0	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	23—28	0	.000
" f	"	7	0	7	0	3	0	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17—20	0	.000
" g	"	7	0	7	0	3	0	3	0	3	1	5	16	6	0	15	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	34—49	17	.410
" h	"	7	5	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7—14	5	.476
8 *	Total	7	7	7	0	3	0	3	1	3	1	5	57	6	0	15	19	8	4	8	0	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Average 36.56	Total 89	Aver .257

* Indicates females that were reared in confinement.

Egg-Laying Records of Individual Females of Phyllophaga Vandinei n. sp.

Exp. Number	Date	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Days	Eggs	Lived Days	Laid Eggs	Eggs per Day
988	8-11	14	1	7	1	7	0															21—28	2	.082
1019 a	9- 1	5	0	9	0	9	0															14—23	0	.000
" b	"	5	0	9	0	9	0															14—23	0	.000
" c	"	5	0	9	0	9	0	4	0	22	0											27—48	0	.000
" d	"	5	0	9	0	9	0	4	0	22	0											27—48	0	.000
" e	"	5	0	9	0																	5—14	0	.000
1020 a	8-26	3	0	2	0	3	0	3	0	6	0	7	0	5	0	4	0	21	0			33—54	0	.000
" b	"	3	0	2	0	3	0	3	0	6	0	7	0									17—24	0	.000
" c	"	3	0	2	0	3	0	3	0	6	0											11—17	0	.000
" d	"	3	2	2	0	3	1	3	1	6	0											11—17	4	.286
" e	"	3	0	2	0	3	0	3	0	6	0											11—17	0	.000
" f	"	3	0	2	0	3	0	3	0	6	0	7	0	5	0	5	0	20	0			34—54	0	.000
" g	"	3	0	2	0	3	0	3	0	6	4	7	0									17—24	4	.195
" h	"	3	0	2	0	3	0	3	0	6	1	7	5	3	1							24 27	7	.275
" i	"	3	1	2	2	3	0	3	0	6	0	7	0	3	0	2	0	5	0	20	0	34—54	3	.068
" j	"	3	0	2	0	3	0	3	0													8—11	0	.000
" k	"	3	0	2	0	3	0	3	0													8—11	0	.000
" l	"	3	0	2	0	3	0	3	0	6	0	7	5	3	0							24—27	5	.196
1032 a	9- 3	3	0	3	0																	3— 6	0	.000
" b	"	3	0	3	0	7	0	8	0													13—21	0	.000
" c	"	3	0	3	0	7	0	8	0	2	0	24	17									23—47	17	.486
" d	"	3	0	3	4																	3— 6	4	.889
" e	"	3	0	3	0	7	0	8	6	2	0	2	0	20	0							25—45	6	.171
" f	"	3	0	3	0	7	0	8	0	2	0	2	0	22	2							25—47	2	.055
" g	"	3	0	3	0	7	0	8	0	2	0	2	0	22	0							25—47	0	.000
" h	"	3	0	3	0	7	0	8	0	4	0											21—25	0	.000
" i	"	3	0	3	0	7	5															6—13	5	.526
" j	"	3	0	3	0	7	0															6—13	0	000
" k	"	3	0	3	0	7	0															6—13	0	.000
" l	"	3	0	3	0	7	4															6—13	4	.421
1052 a	9-25	3	0	4	0	18	0	8	0	8	0	4	0	11	0	10	0	8	19	13	0	74—87	19	.236
" b	"	3	0	4	0	18	0	16	0	4	0	11	0	10	0	8	12	13	0	16	0	87-103	12	.126
" c	"	3	0	4	0	18	0	16	4	15	2											41—56	6	.124
" d	"	3	0	4	0	18	0	16	14	15	3	10	0	8	0	13	0					74—87	17	.210
" e	"	3	0	4	0																	3— 7	0	.000
" f	"	3	0	4	0	18	0	16	10	15	15	10	2	8	0							66—74	27	.386
" g	"	3	0	4	0	18	0															7—25	0	.000
" h	"	3	0	4	0	18	0	16	5	15	1											41—56	6	.124
" i	"	3	0	4	0	18	0	16	0	15	0											41—56	0	.000
" j	"	3	0	4	0	18	0	16	3													25—41	3	.091
" k	"	3	0	4	0	18	0	20	30	11	0											45—56	30	.594
" m	"	3	1	4	0	18	0	20	12	11	0											45—56	12	.238
" n	"	3	0	4	0	18	7	20	0													25—45	7	.200
" o	"	3	0	4	0	18	0	20	0													25—45	0	.000
" p	"	3	0	4	0	18	0															7—25	0	.000
" q	"	3	0	4	0	17	0	3	0	18	7	21	0	8	0							66—74	7	.100
" r	"	3	0	4	0	17	0	3	0	18	23	21	0									45—66	23	.414

Exclusive of reared adults, a total of 75 females were confined singly for eggs, of which number 45 females laid a total of 713 eggs, or an average of 16 eggs each, while 30 females laid no eggs.

Average from the 45 females, .345 eggs per day, or 1 egg each 3 days.
Average from the 75 females, .204 eggs per day, or 1 egg each 5 days.

It is reasonable to believe that those females which did not lay eggs were old females, and were exhausted of eggs before confined. The confined females were collected in the field, and their age from date of first emergence could not therefore be determined. It is believed that the average from the forty females that laid eggs can be taken as nearly the correct or normal figure.

The average length of life of 45 females that laid eggs was 47 days (about one and one-half months); the average length of period of oviposition 11 days (about one and one-half weeks). (The duration of oviposition is taken as including the time between the recorded dates of laying of the first and last eggs in confinement.) As the environment of the beetles in the experimental jars was certainly quite different from that outdoors, it is possible that these figures would be materially lengthened in outdoor or natural conditions.

The greatest duration of the egg-laying period was 42 days (or six weeks), the female laying in that time only 39 eggs, or slightly under one egg per day. The egg-laying period of 25 out of the 45 females was less than one week in duration.

The female that lived the longest in confinement, 95 days (or thirteen and one-half weeks), laid only 12 eggs, all within three days. One female lived 59 days (or eight and one-half weeks) and laid no eggs, being fed, however, during the entire period.

The egg laying of adults is periodical. For instance, in the group of 14 females included in the numbers 1206 to 1219, inclusive, where the average length of life was 56 days, over half of the 188 eggs were laid within six days—between the 30th and 35th days of confinement. Again, in the group of eight females included in the numbers 1284*a* to 1284*h*, inclusive, where the average length of life was 36½ days, over three-fifths of all the 57 eggs were laid in the five days between the 27th and 32d days of confinement. There facts, merely as circumstancial evidence, would make it appear that about a month is required for mature eggs to form in the female uterus after copulation.

The largest number of eggs laid in a short space of time by a female was 35 (see No. 1209), laid in two days, or at a rate of 18 eggs per day.

The data obtained from the females confined "en masse" show that—a total of 1,406 females laid 1,560 eggs in an average period of 6.4 days. Or, reduced to the equivalents of the preceding table of averages:

Average from 60 per cent of females, .29 eggs per day, or 1 egg each 3½ days.
Average from all the females, .172 eggs per day, or 1 egg each 5¾ days.

INSECT PARASITISM.

The insects which prey upon this species are the same as those listed for the genus. Probably one of the more important ones is the predacious wireworm, *Pyrophorus luminosus* Ill., the exact value of which, however, as a control of the grub in the fields it is very difficult to ascertain, from the fact that, in digging or plowing, living wireworms are very rarely found adjacent to the grubs they have attacked.

Other important enemies of *vandinei,* in the more northern part of its range, are the two Tachinid flies which parasitize the adults.

As to the large Scoliid wasp, *Campsomeris dorsata* Fab., it has been found that on the island of Barbados the species, though commonly parasitizing and apparently preferring the Dynastid, *Ligyrus tumulosus* Burm., is occasionally found parasitizing a common Melolonthid, *Phytalus smithi* Arrow (18, p. 56). In Porto Rico this wasp is particularly abundant in the Guánica district, where it has been often found parasitizing *Ligyrus tumulosus* grubs. It is possible that it may rarely attack grubs of *Phyllophaga vandinei;* but to the present date none of the records of its attack of this species have been verified; and the fact is patent that, of many hundreds of grubs of *vandinei* examined by the writer, and many dozens reared in confinement, not one has ever been observed parasitized by egg or larva of this wasp. Dry grub remains have been examined attached to numbers of *Campsomeris* cocoons collected at Santa Rita, but none of them proved to be *vandinei.*

The Tachinid flies.—Two species of Tachinid fly, *Cryptomeigenia aurifacies* Walton (see Pl. VII, fig. 7) and *Eutrixoides jonesii* Walton, which have been previously discussed, are known to attack this species and *portoricensis* in the more humid parts of their habitats, and to do much to keep them in check in those localities. A rather large percentage of specimens of *vandinei* collected at Añasco, at the west end of the Island, have been found infested with the pupæ of *Cryptomeigenia,* and a far smaller number with *Eutrixoides.* Collections of pupæ have been made in April, May and September, but doubtless can be found throughout the year. The number of pupæ

found within one dead adult host varies from two to nine, usually four to six. Infested beetles that have died are always found in their burrows in the ground.

Work on the life-histories of the two species is in progress now, but has not yet been completed.

Neither species has been found to occur in the Guánica district, where the damage from *vandinei* is most acute. Attempts to introduce the flies at Santa Rita, using infested beetles taken there from Añasco, were not successful; and it seems probable that the flies do not thrive in a dry climate like that of the south coast.

Attacked by mites and nematodes.—In the experimental jars and boxes some difficulty was experienced in the rearing of eggs of *vandinei* because of attack by nematodes and mites, the latter apparently a species of *Tyroglyphus*. The following brief notes may serve as examples of the manner in which this loss of eggs occurred:

No. 1016.—August 25, eleven eggs, laid since August 17, were put into artificial cells at bottom of a jar. August 26, one egg destroyed, surrounded by a myriad of young nematodes. August 27, two more similarly destroyed. August 30, all the other eggs but four destroyed by the nematodes.

No. 1021.—August 26, fourteen eggs, laid August 18 to 21, were put into damp sifted earth at bottom of jar. August 27, one destroyed by nematodes and mites. August 29, two more destroyed. September 30, last two killed by mites, and being eaten by them.

The injury from the mites was not limited to the eggs, grubs in all instars often suffering badly, even dying, from their attack. The following notes give specific examples of mite injury to grubs:

No. 1049d.—January 28, a grub in second, molted about December 12, heavily infested with mites. February 17, grub died as result, without being able to molt.

No. 1049g.—January 18, a grub in second, molted about December 20, partly covered with mites on head, legs, and front of body. February 25, molted. June 25, sickly, with many mites. June 30, dead, eaten up by mites.

No. 1193.—May 3, grub preparing to pupate put into box. May 22, died before pupating; covered with mites.

No. 1216d.—May 15, grub in first, hatched May 15, has mites. June 2, injured by mites, and died molting to second.

No. 1309a.—June 18, grub hatched since yesterday put into box. July 29, half covered with mites, which prevent its growth. August 9, sickly, with many mites. August 14, died without molting to second.

Eggs devoured by wireworm and Staphylinid larvæ.—Occasional loss of eggs was experienced in experimental jars from wireworms (*Monocrepidius* sp., undetermined) and from larvæ of a small Staphylinid beetle, introduced into the earth with manure. The following extracts from notes give specific cases:

No. 1032e.—September 24, six eggs, laid since September 17, put over damp earth in a box. September 25, two eggs missing, and a wireworm present, eating a third.

No. 986.—August 14, out of nine eggs, laid August 9–11, placed in artificial cells in earth, two were destroyed by Staphylinid larvæ, which occupied the cavities where eggs had been.

LITERATURE CITED.

(1) Blatchley, W. S.—1910. Lachnosterna (pp. 958–980, fig. 3, pl. 5). *In* The Coleoptera or Beetles Known to Occur in Indiana.

(2) Dash, J. Sydney.—1916. Rept. of the Asst. Supt. of Agr. on the Ent. and Myc. Work Carried Out During the Season Under Review. *In* Rept. on the Dept. of Agr., Barbados, 1914–15 (pp. 38–41).

(3) Chittenden, F. H.—1909. Insects Injurious to Vegetables (lit. pp. 73–78, fig. 3).

(4) Davis, John J.—1913. Common White-Grubs. Farmers' Bull. 543, U. S. Dept. of Agr. (pp. 20, fig. 12).

(5) Davis, John J.—1916. A Progress Report on White-Grub Investigations. *In* Jour. of Econ. Ent., vol. 9. No. 2, 1916 (pp. 261–281 pl. 2).

(6) De Charmoy, D. d'Emmerez.—1912. Rapport sur Phytalus smithi (Arrow) et Autres Scarabees S'Attacquant a la Canne a Sucre a Maurice, Port-Louis, 1912 (pp. 35, pl. 10).

(7) Forbes, S. A.—1907. On the Life-History, Habits, and Economic Relations of the White-Grubs and May-beetles. Bull. No. 116, Univ. of Ill. Agr. Exp. Sta. (pp. 447–480).

(8) Forbes, Stephen A.—1916. A General Survey of the May-beetles (*Phyllophaga*) of Illinois. Bull. No. 168. Univ. of Ill. Agr. Exp. Sta. (pp. 215–257).

(9) Girault, A. A., and Dodd, A. P.—1915. The Cane Grubs of Australia. Bull. No. 2, Div. of Ent., Bu. of Sugar Exp. Stations, Queensland (pp. 60).

(10) Goot, O. van der.—1915. On Certain Beetle Larvæ Found in Sugar Plantations (text in Dutch). Med. Proefstation voor de Java Suikerindustrie, pt. 5, No. 10. Soerubaia, (pp. 60, fig. 13).

(11) Jarvis, E.—1916. Notes on Insects Damaging Sugar Cane in Queensland. Bull. No. 3, Div. of Ent., Bu. of Sugar Exp. Stations, Queensland (pp. 48, four plates).

(12) Johnston, John R.—1915. The Green Muscardine (Metarr-

hizium anisopliæ) *In* The Entomogenous Fungi of Porto Rico, Bulletin No. 10 of the Board of Comm. of Agr. of P. R. (pp. 26–28).

(13) Kulagin, N. M.—1913. The Principal Insect Pests of Field Crops in European Russia for the Last Twenty Years (text in Russian). *In* The Year Book of the Dept. of Agr. of the Central Board of Land Administration and Agriculture, St. Petersburg, VI, 1913 (pp. 585–638, pl. 1).

(14) Leefmans, S.—1915. De Cassave-Oerets (The Cassava Grubs). Dept. Nijverheid, Landbouw en Handel. Med. van het Laboratorium voor Plantenziekten, No. 13, Buitenzorg (pp. 118, pl. 7).

(15) Leng, Chas. W., and Mutchler, A. J.—1914. A Preliminary List of the Coleoptera of the West Indies as Recorded to January 1, 1914. Bulletin of the Am. Mus. of Nat. Hist. vol. 33, art. 30, pp. 391–493.

(16) Moore, W. H. B.—1916. General Report on Insect Pests (of Cane) for the Year 1915. Rept. to Messrs. Booker Bros., McConnell & Co., Ltd., and Messrs. Curtis, Campbell & Co., Demerara (pp. 8).

(17) Northrup, Zae.—1914. A Bacterial Disease of June Beetle Larvæ, *Lachnosterna* spp. Tech. Bull. No. 18, Mich. Agr. Coll. Exp. Sta. (pp. 37, twenty-two figs.).

(18) Nowell, W.—1915. Two Scoliid Parasites on Scarabaeid Larvæ in Barbados. *In* Ann. of Applied Biology, vol. 2, No. 1 (pp. 46–57, pl. 1).

(19) Patterson, Wm. H.—1912. Rept. on the Agr. School, St. Vincent. *In* Reports on the Botanic Station, Agr. School, etc., St. Vincent, 1910–11 (pp. 19–24).

(20) Riley, Chas. V.—1869. The White-Grub. *In* First Report of the Missouri State Entomoligist on the Insects of Missouri (pp. 156–159).

(21) Riley Chas. V.—1874. The Unadorned Tiphia or White-Grub Parasite. *In* Sixth Report of the Missouri State Entomologist on the Insects of Missouri (pp. 123–126).

(22) Shepherd, F. R.—1916. Work Connected with Insect and Fungus Pests and Their Control. *In* Rept. of the Agr. Dept., St. Kitts-Nevis, 1914–15 (pp. 15–16).

(23) Smyth, Eugene G.—1915. Report of Work at the South Coast Laboratory. Third Report of the Board of Comm. of Agr. of Porto Rico (pp. 40–53).

(24) Smyth, Eugene G.—1916. Report of the South Coast Labora-

tory. Fourth Report of the Board of Comm. of Agr. of Porto Rico (pp. 45–50, with life-cycle tables).

(25) Stevenson, John A.—1916. Work with the Green Muscardine in Report of the Pathologist. *In* Fourth Report of the Board of Comm. of Agr. of Porto Rico (pp. 34–35).

(26) Tempany, H. A.—1916. Work Connected with Insect and Fungus Pests and Their Control. *In* Report on the Botanic and Experiment Stations, Antigua, 1914–15 (pp. 20–22).

(27) Van Dine, D. L.—1911. Third Report of the Entomologist. *In* Year book of the Association of Sugar Producers of Porto Rico, 1910–11 (pp. 43–57).

(28) Van Dine, D. L.—1912. Report of the Entomologist. *In* Second Annual Report of the Exp. Sta. of the Sugar Producers' Association of Porto Rico (pp. 15–22).

(29) Van Dine, D. L.—1912. Progress Report on Introductions of Beneficial Parasites into Porto Rico. *In* First Report of the Board of Comm. of Agr. of Porto Rico (pp. 31–47).

(30) Van Dine, D. L.—1913. The introduction of Parasites of May-Beetles into Porto Rico. *In* Second Report of the Board of Comm. of Agr. of Porto Rico (pp. 36–48).

(31) Van Dine, D. L.—1913. Report of the Entomologist (with list and bibliography of Porto Rican sugar-cane insects). *In* Third Report of the Porto Rican Sugar Producers' Exp. Sta. (pp. 25–46).

(32) Vassiliev, I. V.—1914. Short Notes on *Anisoplia austriaca* Herb. and Methods of Fighting It (in Russian). *In* Memoirs of the Bureau of Entomology of the Scientific Committee of the Central Board of Land Administration and Agr., St. Petersburg, VII, No. 2 (pp. 36, fig. 20, colored pl. 2).

(33) Washburn, F. L.—1908. Destruction of Lawns by the White-Grub. Circular of Information No. 11, Office of State Entomologist, Minnesota (pp. 2, fig. 4).

(34) Wolcott, George N.—1913. Report on a Trip to Demerara, Trinidad and Barbados during the Winter of 1912. *In* Third Report of the Sugar Producers' Association Exp. Sta. (pp. 47–68).

(35) Wolcott, George N.—1914. Notes on the Life-History and Ecology of *Tiphia inornata* Say. *In* Jour. of Econ. Ent., vol. 7, No. 5 (pp. 382–389).

(36) Wolcott, George N.—1915. Report of the Traveling Entomologist. *In* Third Report of the Board of Comm. of Agr. of Porto Rico (pp. 25–40).

EXPLANATION OF PLATES.

PLATE II.

Fig. 1.—Banana tree stripped of foliage by May-beetles, chiefly by *Phyllophaga vandinei* n. sp.

Fig. 2.—Leaf of a coconut palm injured by the feeding of adults of *Phyllophaga portoricensis* n. sp.

Fig. 3.—Salcilla tree (*Schrankia portoricensis*), a wild species abundant in the Guánica district and whose foliage is much relished by adults of *P. vandinei;* adaptable for use in collecting the beetles in large numbers by shaking.

Fig. 4.—A bushel of adults of *P. vandinei* collected in one evening by nine boys in a cane field at Santa Rita, near Guánica.

PLATE III.

Fig. 1.—*Phyllophaga vandinei* n. sp., eggs lying over soil, x 2 (the elongate egg marked with an "x" is that of *Pyrophorus luminosus* Illiger, an Elaterid whose larva is predaceous on white-grubs).

Fig. 2.—*Phyllophaga vendinei* n. sp. grubs just hatched from eggs, x 3.

Fig. 3.—*Phyllophaga vandinei* n. sp. grubs at end of first instar, x 2.

Fig. 4.—*Phyllophaga vandinei* n. sp. grub at end of second instar, x 2.

Fig. 5.—*Phyllophaga vandinei* n. sp. grub in act of molting to third instar, x 5.

Fig. 6.—*Phyllophaga vandinei* n. sp. grub at beginning of the third instar, x 2.

Fig. 7.—*Phyllophaga vandinei* n. sp. mature grub (at end of third instar), x 2.

Fig. 8.—*Phyllophaga vandinei* n. sp. prepupa (grub about to pupate), x 2.

Fig. 9.—*Phyllophaga vandinei* n. sp. pupa, side view, showing shed larval skin, x 2.

Fig. 10.—*Phyllophaga vandinei* n. sp. pupa at point of issuing of adult, x 2.

PLATE IV.

Fig. 1.—*Phyllophaga vandinei* n. sp., pupa, ventral view, x 2.

Fig. 2.—*Phyllophaga vandinei* n. sp. pupa, dorsal view, x 2.

Fig. 3.—*Phyllophaga vandinei* n. sp. male adult, x 2.

Fig. 4.—*Phyllophaga portoricensis* n. sp., female adult, x 2.

Fig. 5.—*Phyllophaga portoricensis* n. sp. male adult, x 2.

Fig. 6.—*Phyllophaga vandinei* n. sp. adult just issued from pupa, x 2.

Fig. 7.—*Phyllophaga vandinei*, n. sp. adult attacked by *Meterrhizium*, dorsal view, x 2.

Fig. 8.—*Phyllophaga vandinei* n. sp. same, side view, x 2.

Fig. 9.—*Phyllophaga vandinei* n. sp. larva infested with *Metarrhizium*, x 2.

PLATE V.

Fig. 1.—*Phyllophaga vandinei* n. sp. heads of grubs in first instar, x 10.

Fig. 2.—*Phyllophaga vandinei* n. sp. head of a grub in second instar, x 10.

Fig. 3.—*Phyllophaga vandinei* n. sp. head of a grub in third instar, x 10.
Fig. 4.—*Phyllophaga guanicana* n. sp., male genitalia, x 6 (with mm. scale).
Fig. 5.—*Phyllophaga citri* n. sp., male genitalia, x 6.
Fig. 6.—*Phyllophaga vandinei* n. sp., male genitalia, x 6.
Fig. 7.—*Phyllophaga portoricensis* n. sp., male genitalia, x 6.
Fig. 8.—*Phyllophaga citri* n. sp., female genitalia, x 5½ (ventral view).
Fig. 9.—*Phyllophaga portoricensis* n. sp., egg in pit made by the ovipositor, x 6.
Fig. 10.—*Phyllophaga portoricensis,* female genitalia, x 5½ (ventral view).

Plate VI

Fig. 1.—Black birds (*Holoquiscalus brachypterus*) following a plow in cane field at Santa Rita to pick up white grubs.
Fig. 2.—*Phyllophaga guanicana* n. sp., egg lying over soil, x 2.
Fig. 3.—*Phyllophaga guanicana* n. sp., swollen eggs in the natural pits, x 6.
Fig. 4.—*Phyllophaga guanicana* n. sp., grub at end of second instar, x 2.
Fig. 5.—*Phyllophaga guanicana* n. sp., mature grub (end of third instar), x 2.
Fig. 6.—*Phyllophaga guanicana* n. sp., male adult, x 2.
Fig. 7.—*Phyllophaga guanicana* n. sp., female adult, x 2.
Fig. 8.—*Phyllophaga citri n.* sp., male adult, x 2.
Fig. 9.—*Phyllophaga citri* n. sp., female adult, x 2.

Plate VII.

Fig. 1.—*Phytalus insularis* n. sp., eggs lying over soil, x 3.
Fig. 2.—*Phytalus insularis* n. sp., grubs at end of third instar, x 3.
Fig. 3.—*Phytalus insularis* n. sp., pair of adults, x 3.
Fig. 4.—*Phytalus insularis* n. sp., head of adult below that of *Phyllophaga vandinei* to show comparative size, x 6.
Fig. 5.—*Phytalus insularis* n. sp., anal aspect of female adult (with scale in milli meters to show size), x 6.
Fig. 6.—*Phytalus insularis* n. sp. anal aspect of male adult, x 6.
Fig. 7.—*Cryptomeigenia aurifacies* Walton, adult (right) and pupal case (left), x 3.
Fig. 8.—*Tiphia inornata* Say, adult male at right, adult female at left over the cocoon.

Plate VIII.

Life-cycles of individual females of *Phyllophaga vandinei* n. sp. in Porto Rico.

Plate IX.

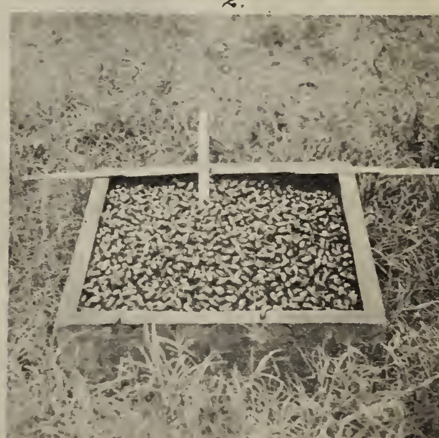
Egg-laying records of individual females of *Phyllophaga vandinei* n. sp.

Plate II.—Porto Rican Melolonthids.

1.

2.

3.



4.

Plate III.—Porto Rican Melolonthids.

Plate IV.—Porto Rican Melolonthids.

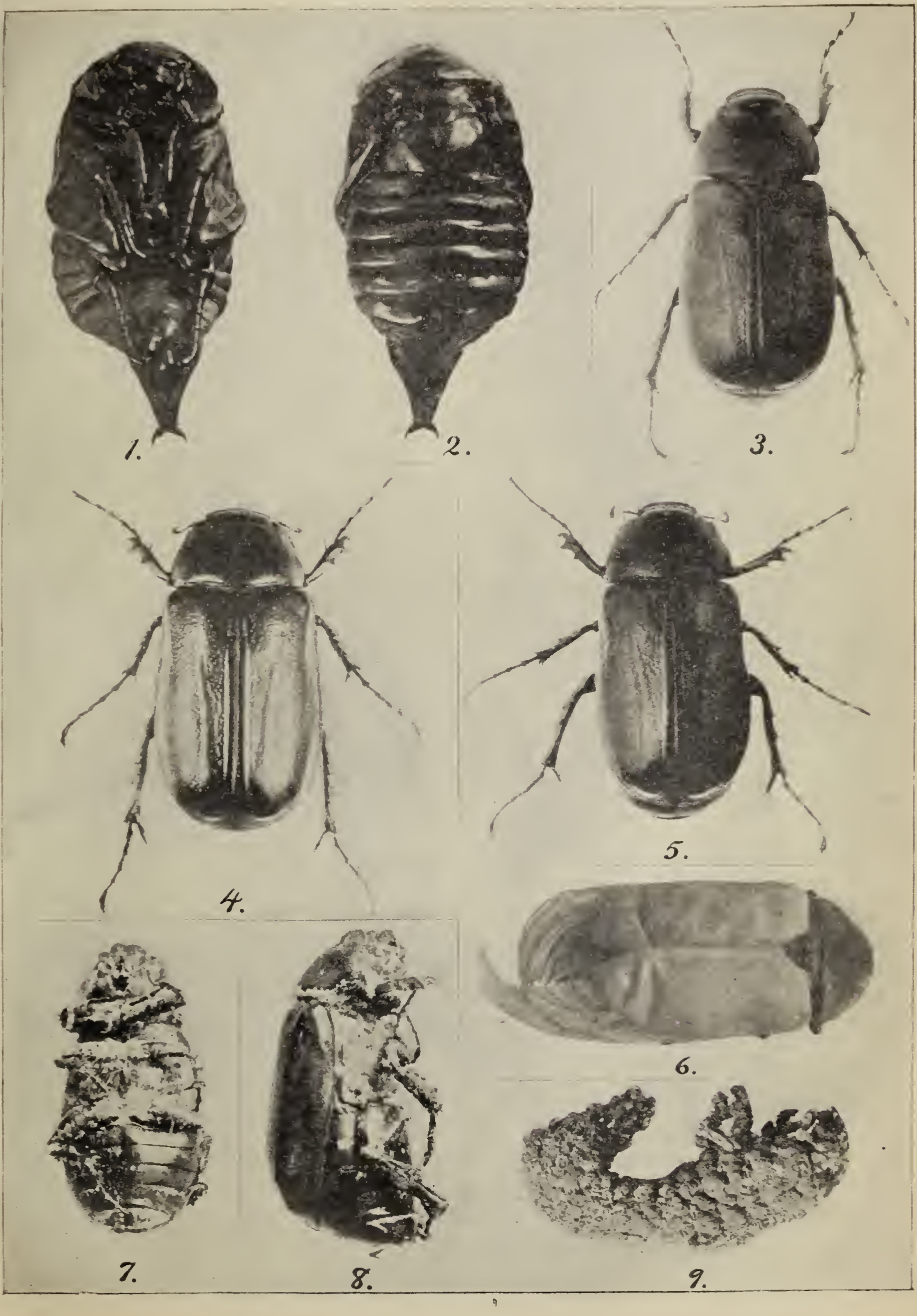


Plate V.—Porto Rican Melolonthids.

Plate VI.—Porto Rican Melolonthids.

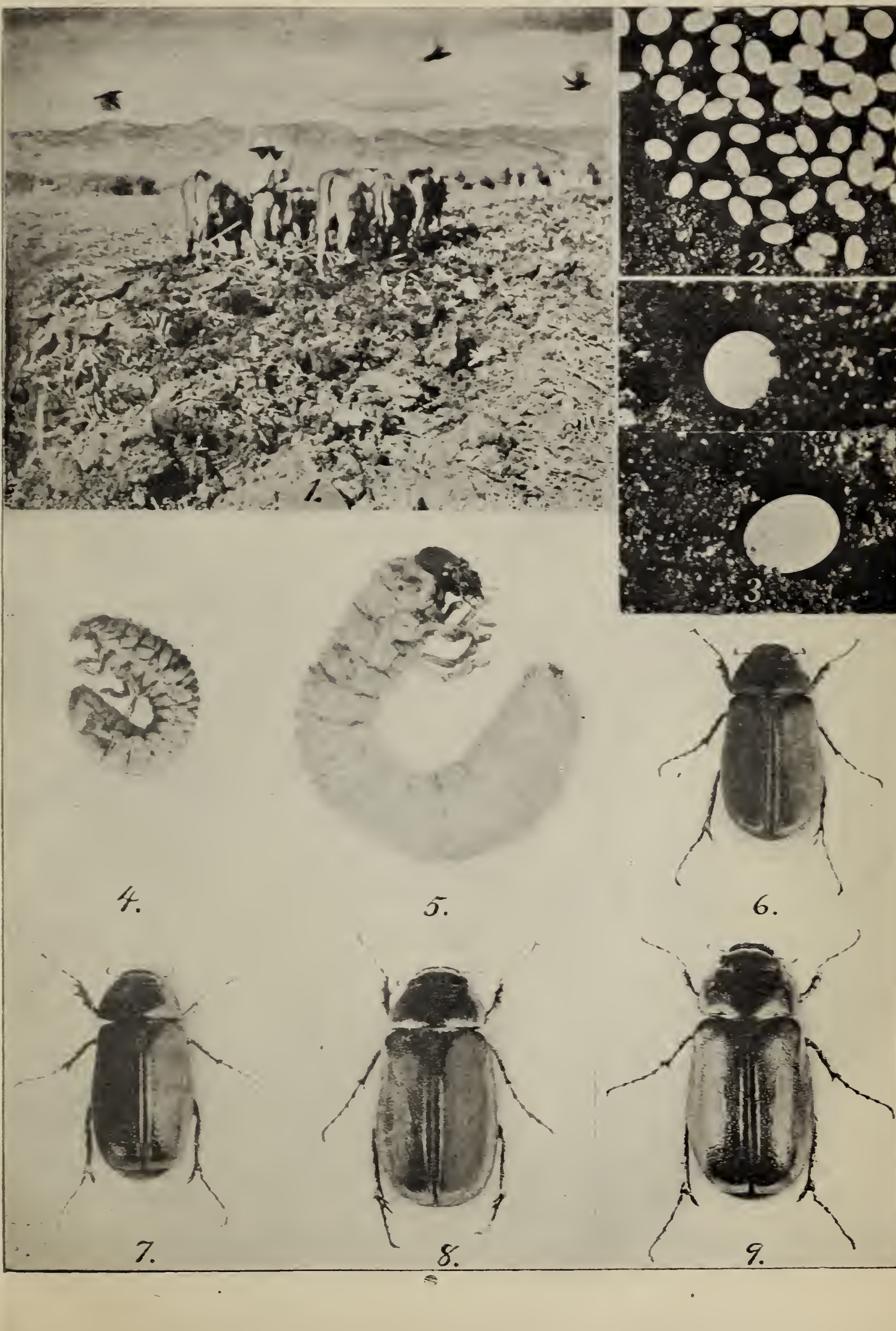


Plate VII.—Porto Rican Melolonthids.

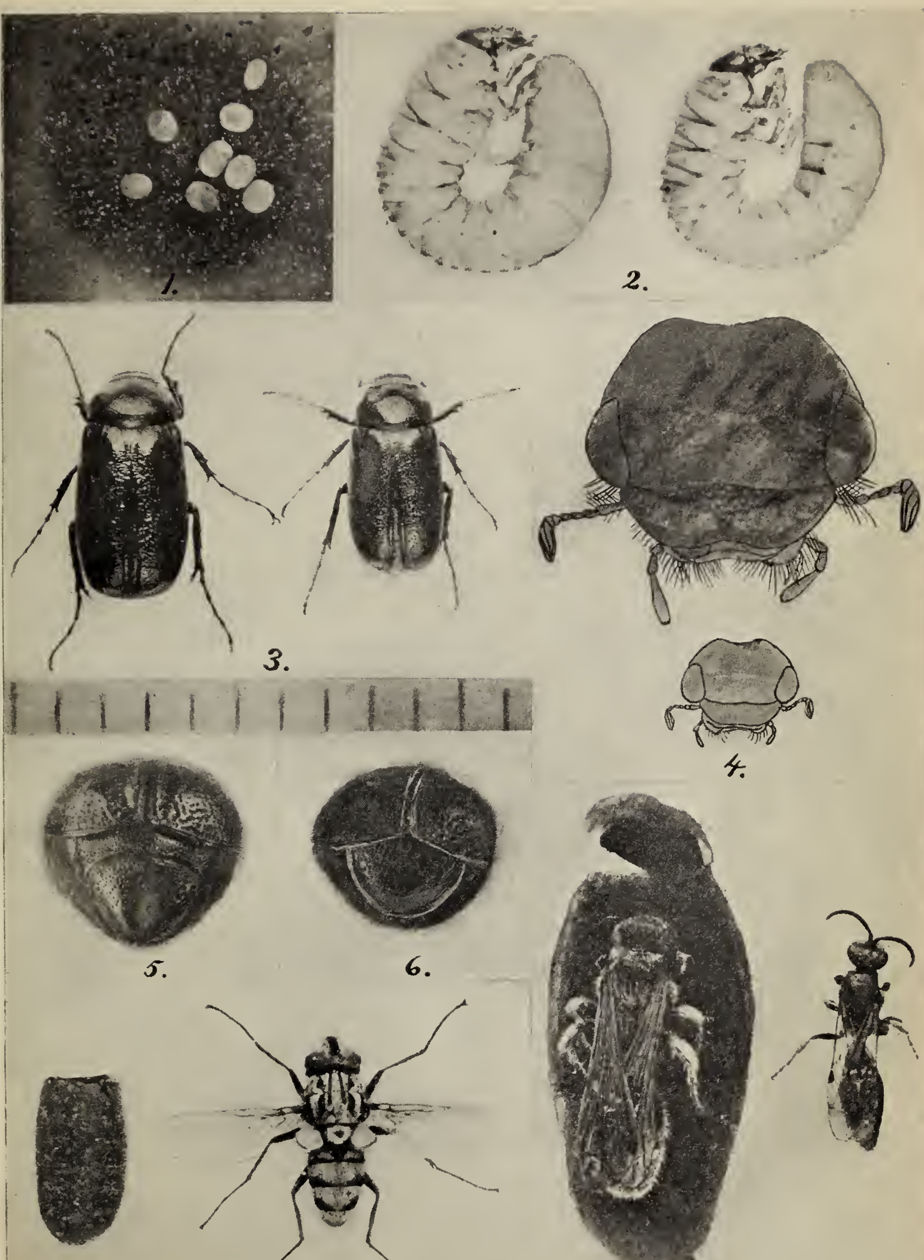


Plate VIII.—Life-Cycles of Individual Females of Phyllophaga Vandinei n. sp. in Porto Rico.

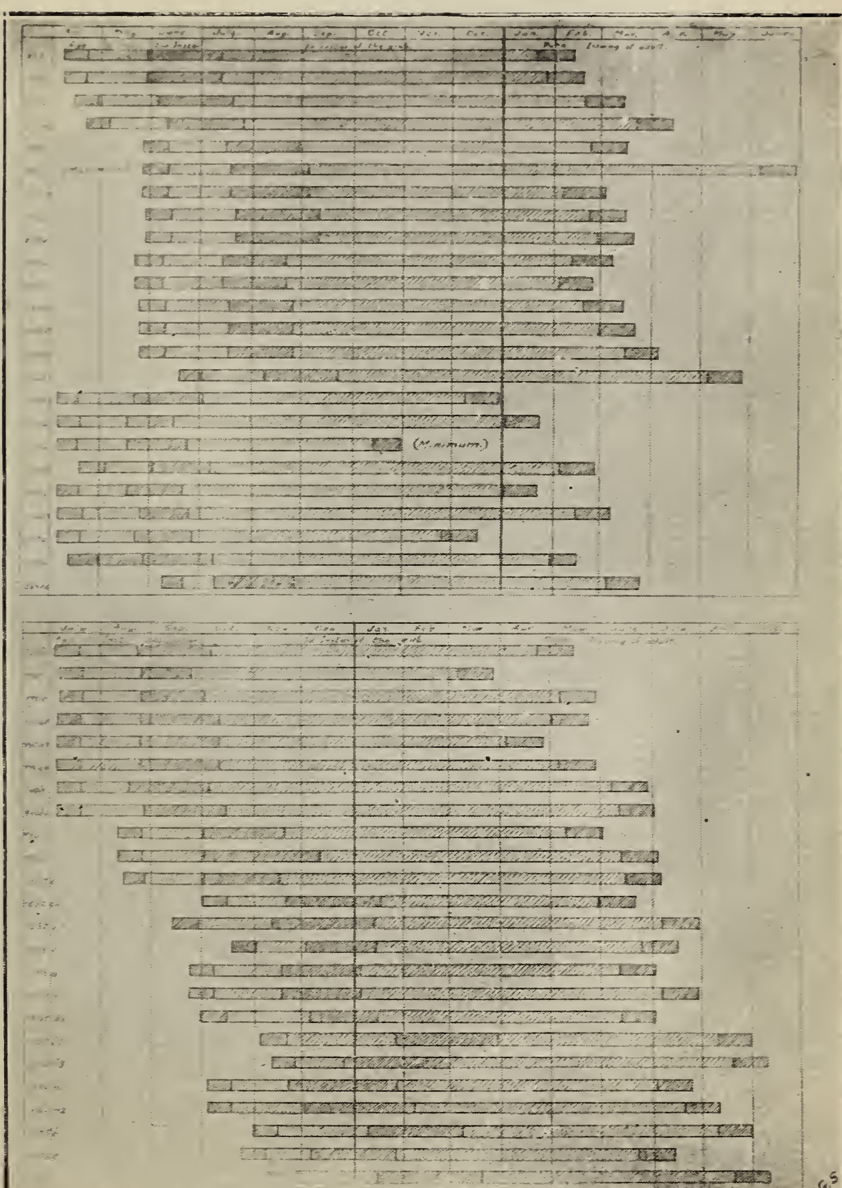
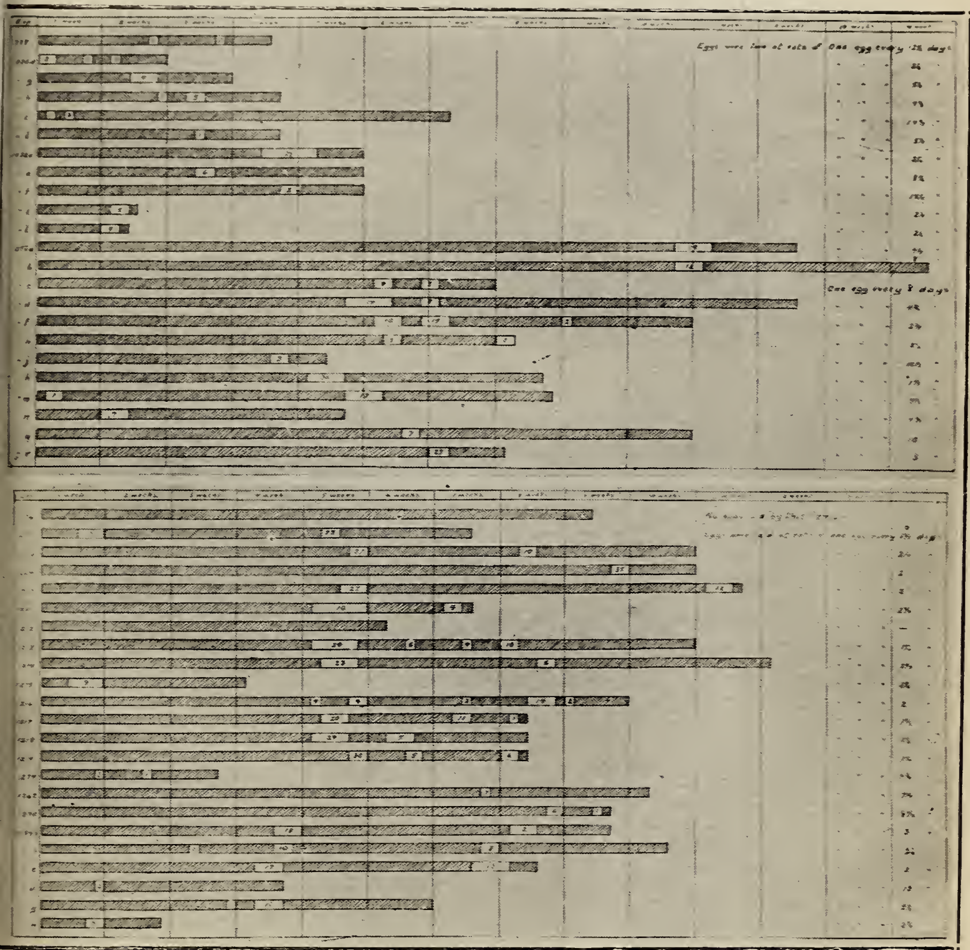


Plate IX.—Egg-Laying Records of Individual Females of Phyllophaga Vandinei.



DISEASES OF VEGETABLE AND GARDEN CROPS.

By JOHN A. STEVENSON, Pathologist, Insular Experiment Station.

In making inquiries among the agriculturists of the Island as to why the growing of the common northern vegetables was not taken up for at least a home supply, the reply has universally been that all such attempts ended in failure. At times with the weather favoring one crop would be secured, but a second was apparently impossible. While it was realized that tropical weather conditions would not be conducive to the best growth of northern vegetables, still it was difficult to see why such complete failures resulted. Consequently a close watch was kept on the various trial plots at the Station and in so far as possible upon gardens in other parts of the Island; in particular the public gardens and those maintained in connected with the normal school at Río Piedras.

As a result observations have been made upon a very large number of fungi causing diseases of the various garden crops. In some cases these have attacked with such virulence as to readily explain the numerous failures reported, especially those with cucumbers and tomatos. Practically all of the troubles so far observed are those of common occurrence in continental America and have all doubtless been introduced with the seed or other plant parts. Many interesting questions have arisen in the work with these diseases especially as regards their dependence upon weather conditions (temperature and humidity), their relation to insects as spore carriers, and above all their modes of attack. Soil and cultural conditions have likewise played an important part. Some of these points will be touched upon in the separate account of the diseases to follow, but others must be deferred until more detailed investigations can be carried out.

Some previous work has been done on the diseases of vegetables in Porto Rico, but with the exception of short notes of occurrence in reports of the Mayagüez Experiment Station, there are no published records. In Bulletin 7 of that Station, issued in 1906, reference is made, in connection with cultural directions for the various vegetables, to certain of the more common diseases and some suggestions for control are made. Certain ones are definitely reported as found in Porto Rico, but for the most part it is impossible to tell whether a given disease is so reported or whether the note is merely

a warning against a trouble that may appear. In the following account such data as the records of this office afford are reported, including for the purpose of completeness other published notes.

Very little has been attempted as yet in the way of control of the fungus diseases here given. Such experiments as time has permitted will be touched upon in the individual discussions which follow. It may be noted, however, that these have been rather uniformly unsuccessful and that methods other than those commonly advised for northern conditions must be tried.

Notes and observations on the various diseases found or reported follow, arranged topically under the various host plants.

Asparagus (*Asparagus officinalis*).

In so far as noted this crop has not been grown successfully, although there have been reports of fair yields. The few plants seen had produced a fair growth of top but no edible shoots. An undetermined imperfect fungus, causing black lesions on the stems, has been found on old or dying plants. The rust (*Puccinia asparagi*) does not occur.

Beans (*Phaseolus* spp.).

Two plantings of this crop were made at the Insular Station, one in February and the other in May on separate pieces of land. It is of interest to note that the diseases occurring on the first planting were lacking or of minor importance on the second; a state of affairs doubtless to be attributed in part to weather conditions and in part to the use of seed from various sources infected with different diseases.

As will be noted below there was a marked varietal resistance to the different diseases and a solution of the problem seems most probable through the use of resistant varieties. Native types already exist which thrive very well, and doubtless others will be found in the course of the experimental work which will be even more thrifty and disease resistant.

Anthracose, Spotting of Pods (*Colletotrichum lindemuthianum* [Sacc. & Magn] Scribner).—This well-known disease has been very prevalent and forms one of the greatest obstacles to successful bean culture in Porto Rico. It has been commonly observed on green beans of local varieties offered for sale in the native shops, as well as on the northern types tried experimentally.

The pods, leaves, and stems were subject to attack. On the leaves the disease was noted as irregular, red-brown spots or more com-

monly as lesions along the midrib and principal veins. Susceptible varieties lost a large percentage of their leaves. Similar lesions also occurred on the stems and petioles, several such often uniting so as to involve practically their entire length. Young plants were in some cases completely girdled, resulting in speedy death, and in other instances they were so seriously weakened that little growth was made. On the pods very characteristic spots occurred. These appeared first as circular dark-brown areas, soon becoming sunken, and often coalescing to form irregular cankers. In each of these spots there was an abundant production of conidia (reproductive bodies) occurring in the form of numerous pink masses, so that at this stage the spots had a decided pink color. The fungus grows from these spots into the seeds, where it remains dormant until germination occurs, when it attacks the young plant. The necessity of selecting seed from disease-free pods will be apparent, since there is no method of destroying the fungus present without destroying at the same time the vitality of the seed.

As soon as the presence of anthracnose was noted spraying tests with Bordeaux mixture were initiated. Two applications were made. While it is impossible to draw definite conclusions from the results of one year's tests on a small plot, it seems apparent that spraying, with Bordeaux at least, is not effective, a conclusion which workers in other regions have also reached. Here as elsewhere the solution of the problem lies in the production of resistant varieties, a matter which has already been taken up by the plant breeder with excellent prospects of success. A black Venezuelan bean has so far given excellent results, and if it maintains its freedom from disease will be very satisfactory.

The first trials included the following varieties arranged here in their order of susceptibility as indicated by one season's tests in short parallel rows:

	Per cent of pods spotted.
Saddle black wax	42
Burpees round yellow, six weeks bush	34
Improved black wax	32
Hendesons bountiful bush	21
Extra early refugee	10
Early bountiful bush	8
Early red valentine bush	7
Curry's golden wax rust proof	5

This arrangement is based upon observations of the severity of infection on leaves and stems and upon counts of the pods, classifying them as free of spots, spotted and rejected. This count seemed

to show some benefit from the spraying, but the plantings were not large enough to give conclusive evidence. It is doubtful whether spraying will prove effective enough to pay for the additional expense. It must be noted with regard to varietal resistance that seed infection, a most important point, was not considered.

Later in the season a second crop of beans was grown on a neighboring plot of ground. The varieties were refugee, 1000–1 (both northern types), a black Venezuelan bean, and the native red bean. Only the slightest trace of anthracnose appeared, and this on the "refugee." Whether this freedom from disease was attributable to weather conditions, to clean seed or to varietal resistance was not apparent. Further tests are necessary.

Downy Mildew.—A virulent disease, caused by a fungus of the *Phycomycetes* or alga-like fungi, attacked the refugee and 1000–1 beans of the second planting. The Venezuelan black wax and native red types in adjacent parallel rows were unaffected. The trouble appeared over night practically, and within a week had destroyed large portions of the plantings.

A plant once attacked rapidly succumbed, the leaves wilting and drooping in such a way as to suggest root troubles, but examination of early stages revealed healthy stems and roots, the tops being attacked first. The withering and consequent death of an infected plant, however, occurred very speedily. At times single plants only were attacked, but more commonly entire sections of a row up to eight or ten feet in length were killed, the disease spreading rapidly from the original point of infection. The most striking feature of this disease was the fungus growth on the pods occurring as flocculent (fluffy) white masses of mycelium obscuring the upper half of, or even at times the entire length of, the pod. Attacked pods were destroyed by soft rot.

The damage that this disease would be capable of, if bean growing were attempted on a commercial scale, was well illustrated by the fate of a peck of the refugee variety which was left for several days in the picking basket. When examined the entire lot had been matted together by the mycelial masses of the fungus and completely soft-rotted. Shipping this variety at least would have been a decided failure.

Time has not permitted any further studies of this disease. Hence the systematic position of the fungus involved has not been determined. It is not *Phytophora phaseoli* Thaxter, which fungus, however, has been reported (5)[1] on lima beans in Porto Rico.

[1] Reference is made by number to "Literature cited," p. 117.

GRAY LEAF-SPOT (*Isariopsis griseola* Sacc.)—On the first planting spots due to this fungus were rare, but on the second were fairly abundant on the northern varieties. The black Venezuelan remained free. A native variety of the red kidney type was noted, in which the entire planting was spotted to such an extent as to cause a heavy dropping of leaves and consequent weakening of the plants. It is a common disease in native plantings. It can doubtless be controlled by Bordeaux mixture.

This disease was characterized by irregular, brownish gray to gray spots on the leaves up to half an inch in diameter. The spots differed from those due to *Cercospora* in that they were duller in color and lacked the definite red-brown angular margin. The fungus fruited freely in the center of the spots and appeared under a hand lens as numerous erect, rather compact, black clusters of conidiophores or conidia-bearing threads.

LEAF SPOTS (*Cercospora* spp.)—At least one other type of leaf spot occurred. The one commonly found and due to *Cercospora canescens* Ell. & Martin was collected on varieties of *Phaseolus vulgaris* (common bean), *Dolichos lablab,* and *Phaseolus lunatus* (lima bean). The spots due to this fungus were more or less angular, up to one-fourth inch in diameter, gray with a reddish brown definite margin, and their appearance was the same on both sides of the leaf. A specimen of *Cercospora cruenta* Sacc. collected on bean in Porto Rico is in the herbarium of the New York Botanical Garden. *Dimerium grammodes* (Kuntze) Gar. is reported on *Phaseolus lunatus* by Garman (9).

POWDERY MILDEW (*Erysiphe polygoni* DC?).—A powdery mildew appeared on the leaves of several of the varieties after the crop had been gathered and the plants were past maturity. Only unsprayed portions of the rows were attacked. It is of very minor importance since only old, unsprayed plants were found subject to it. The determination can be only provisional since the imperfect or *Oidium* stage only was found.

CROWN ROT (*Fusarium* sp.)—A crown rot or damping-off was noted to a very limited extent attacking the native red variety. Sunken lesions occurred on young plants at the ground level and extended for an inch or two along the stem, accompanied by a scanty production of white mycelium of a *Fusarium* sp. This was later noted on northern varieties, attacking young plants at various stages up to six inches in height, in some cases isolated plants only, in others accounting for several plants in a group or even a dozen or

more. The *Fusarium* found is apparently the same as causes a "damping-off" of tomato and eggplant seedlings.

BLIGHT (*Bacterium phaseoli* Sm.).—While this disease has not been definitely identified by exact methods, there can be but little doubt of its presence on northern varieties, but fortunately to a very limited extent only.

RUST (*Uromyces appendiculatus* [P.] Lk.)—The bean rust is known to occur on the Island, but has not been collected on the cultivated bean at this Station, although of common occurrence on several of the wild legumes (*Phaseolus adenanthus, Vigna repens*), etc. It forms very small, but numerous brown powdery eruptions on leaves and pods. It is not of sufficient importance to warrant control measures.

ROOT ROT OR WILT.—As many as four types of root rot or wilt are reported (5, 1). *Cercosporium* (?) *beticola* is given as the possible cause of one form. No further notes are given. This type of disease has not been observed during the present investigations.

BEET (*Beta vulgaris*).

The leaf spot (*Cercospora beticola* Sacc.) has been the only disease so far observed on this host. The death of mature leaves was somewhat hastened, but no further damage resulted. The spots were numerous, of the same appearance on both sides of the leaf, circular, brown at first, but later dull gray to dirty white, with definite red-brown margins. The Swiss chard (*Beta vulgaris* var.) was also attacked, whenever the leaves were allowed to come to maturity.

CABBAGE (*Brassica oleracea*).

Cabbage remained comparatively free of disease, although not making a very satisfactory growth. A soft, putrid, bacterial rot destroyed individual plants which had been injured in cultivating. Diseases due to *Pseudomonas campestris, Plasmodiophora brassicae, Peronospora parasitica*, and *Macrosporium brassicae* are mentioned by Henricksen (5), but are not definitely reported as found in Porto Rico.

CELERY (*Apium graveolens*).

Celery was slightly attacked by rootknot (*Heterodera radicicola*), which is described in detail later. Leaf spot due to *Septoria petroselini* Desm. was not found.

CASSAVA (*Manihot utilissima*).

WITHERTIP (*Gloeosporium manihot* Earle).—In one locality a sweet (non-poisonous) variety of cassava was suffering severely from die back induced apparently by poor soil, and prolonged drouth, aided by the fungus in question. There was a characteristic withering and dying of the leaves which remained hanging at the tips of the twigs. The twigs and even the branches died back for a considerable distance, at times nearly to the ground level. Examination of the underground portions of the plants revealed no indications of disease. On the dead twigs the fungus formed small black fruiting pustules. Under favorable conditions this disease probably will give no trouble, though removal of diseased portions and cultivation should suffice to check it if it should by any chance get a start.

LEAF SPOT (*Cercospora henningsii* Allesch.)—The characteristic leaf spots due to this fungus are common but of no great importance. They are angular, small (seldom over one-eighth inch in diameter), and dull white or gray in color, with a definite reddish-brown margin.

RUST (*Uromyces janiphae* [Wint.] Arthur.)—Not common, producing brown, powdery pustules on the under sides of the leaves. A root rot has also been reported (8) on this host.

CHAYOTE (*Sechium edule*).

The chayote is very subject to one or more leaf diseases which very often completely destroy the plant, frequently before any fruit has been produced. Spraying with Bordeaux mixture has not given satisfactory results in so far as observations have been made, nor do published records report any success along this line (5).

Miss Young (7) describes one type of leaf spot due to *Phyllosticta Sechii*. The spots caused by this fungus are said to be amphigenous, more or less irregular, often confluent, varying in size from two to twelve millimeters and dull white in color. Minute dark brown or black pycnidia are produced in the center of the spots on the upper surface of the leaves.

A second and much more virulent type of leaf spot occurs. This is due to an apparently undescribed species of *Cercospora* or preferably *Helminthosporium*. The spots are angular, up to ten millimeters in diameter, dull brown above, lighter below, sometimes becoming a dull white at the center in old spots, margins definite, fruiting on both surfaces. The leaf area between the numerous spots speedily dies and the leaf withers and drops. This disease presents

a very serious obstacle to the successful culture of the chayote. All of our collections of leaf spot on this host have been of this latter type, pycnidia of *Phyllosticta* being found in only one very old spot, making it appear probable that the *Phyllosticta* is but secondary when present at all.

A root rot has been reported by some growers, but no data has been secured.

Corn (*Zea mays*).

Both the rust and smut were observed, the latter less commonly. The rust *Uredo pallida* Diet and Holw.) attacked the older and lower leaves, generally at a time when the ears were nearly mature so that little damage could be attributed to it. It appeared as numerous small brown pustules on the under side of the leaves.

The smut (*Ustilago zeae* [Beck] Ung.) attacked all parts of the plant, distorting or destroying them, and forming irregular masses covered by a white membrane, which broke away, liberating the black, powdery, spore mass. It is of no importance in Porto Rico as yet.

A third disease occurred quite commonly, but is of no economic importance as yet. This is manifested as numerous black, carbonous slightly raised spots on the leaves (both surfaces) and leaf sheaths in which the spore-bearing bodies are produced. Each spot is surrounded by a yellow or brown circle of dead tissue. The death of old or basal leaves is hastened, especially when the rust is also present as is usually the case. The fungus is *Phyllachora graminis* (Pers.) Fuckel.

Cowpea (*Vigna unguiculata*).

This legume has been used in some gardens between crops to improve the soil. Certain varieties thrive very well and their increased use is recommended. The iron variety is especially good for growing in this connection since it is not subject to nematodes, and in so far as observed does well under Porto Rican conditions. Other varieties are cultivated to some extent under the name of "frijoles" as food plants. Most of these latter types are, however, very subject to root-knot and proper precautions must be taken to avoid this trouble.

Leaf Spot (*Cercospora vignae* Racib.)—This leaf spot as mentioned in a previous report (10) caused defoliation of an unknown variety of cowpea (not the iron) grown at the Station. The spots were numerous, circular, up to one centimeter in diameter, reddish brown in color, with distinct margins, and soon confluent, causing the death of the leaf.

Gray Leaf Spot (*Cercospora cruenta* Sacc.)—This leaf spot was found on one of the native edible seeded varieties, causing a serious weakening of the plants and partial defoliation. The diseased areas were angular to indefinite, three to eight millimeters in diameter at first, but rapidly coalescing, a dirty gray in color below, due to the copious production of conidia and conidiophores and yellowish or chlorotic above, becoming dull rust red. Would doubtless be controlled by Bordeaux or other fungicide.

On the iron cowpea a powdery mildew (*Erysiphe polygoni* DC?) was noted in several instances, but causing little harm. The *Oidium* stage only of the fungus was present.

Cucumber (*Cucumis sativus*).

Attempts to grow cucumbers in Porto Rico have been particularly disastrous. In some instances a splendid first crop has been obtained, but the second almost invariably fell prey to disease. A similar state of affairs occurred in the Station trials. The cause was largely the disease known as downy mildew and described below. Successful cucumber culture will depend upon its control.

Downy Mildew (*Pseudoperonospora cubensis* [B & C] Clinton.)—This disease was characterized by indefinite yellow spots on the leaves, which under the humid conditions existing here were so numerous or so rapidly coalesced that the death of the leaves quickly resulted. The superficial growth of the fungus itself could be seen as a delicate grayish purple layer on the under side of the leaves. The older leaves were attacked first and the disease progressed with the growth of the vines, usually three to four leaves behind the growing point. In wet weather, however, the leaves were attacked before they were completely unfolded, and in the second planting the cotyledons (seed-leaves) were attacked and destroyed before the second leaf had completely unfolded.

The mildew appeared on the first planting when the vines were about a foot long and had developed from four to seven leaves. Bordeaux mixture at a strength of 3–3–50 was immediately applied and additional applications made at weekly intervals until March 2, or eleven sprayings in all. As far as it was possible to observe spraying was without practicable results, except that aphids developed unchecked by fungus (*Acrostalagmus albus* ?). The disease progressed in the same degree upon sprayed plants and checks. Marketable cucumbers were secured for a time, but the disease finally gained the upper hand and the few fruit set after that time were small and misshapen.

Even worse results were obtained with the second crop planted in the same beds as the first. As noted the disease attacked the plants almost as soon as the first leaf was formed, although the first spraying had already been given. In all nine sprayings of Bordeaux (3–3–50) were made at three to four-day intervals. Practically no salable fruits were produced, the vines making little growth after the first few weeks.

One peculiar circumstance was noted after the beds were abandoned. Certain of the plants which had not been killed outright made considerable new growth, free of disease, and even produced normal fruit after the weeds had grown up around them, in spite of rather heavy rains. This circumstance suggests that infection occus from the soil. Another year it is proposed to experiment with mulching and the training of the vines off the ground, since it is apparent that spraying is ineffective under Porto Rican conditions.

This disease has been reported as occurring upon various other wild and cultivated members of the cucumber family, but except for the melon no other hosts have as yet been found. Species examined have been:

Luffa cylindrica	Esponja.
Momordica charantia	Cundeamor.
Sechium edule	Chayote.
Lagenaria leucantha	Pipe gourd.
Cucurbita pepo	Calabazo, squash.

ANTHRACNOSE.—Ripe cucumber fruits and particularly the nubbins exposed to the sun on the nearly leafless, mildew-infected vines were attacked by anthracnose (*Colletotrichum lagenarium* [Pers.] E & H). The black fruiting spots of the fungus occurred in more or less circular sunken spots on the exposed surface and also on the indefinite dull white corky areas due primarily to sunburn. Various other saprophytic fungi were also present in such cases.

A fungus apparently referable to *Phyllosticta cucurbitacearum* Sacc. was found under the same conditions as the anthracnose fungus. In this case the grayish or dirty white irregular areas were dotted with the minute black pycnidia (fruiting bodies).

Neither the fungus nor bacterial wilt nor any form of damping off were observed.

EGGPLANT (*Solanun melongena*).

As was the case with the beans, one serious disease attacked the first planting and another quite distinct, the second. It was not possible to determine from the data of one season whether this was

due to weather, varietal differences, infected seed, or to a combination of various causes.

ANTHRACNOSE (*Gloeosporium melongenae* E & H).—The first planting was of the long purple variety and for some time was quite free of disease. When in full bearing the fruit on certain plants was attacked by anthracnose, which from that time on increased until at the time the bed was abandoned and the plants pulled, practically all of the fruit on all plants was affected. It seems probable that the fruit on naturally weak plants was attacked first, and then as the other plants were weakened through nematode attacks and other agencies, the disease spread to all. The fact that, owing to lack of a market, the fruit was not picked more than a few times doubtless assisted.

The disease was characterized by sunken, more or less circular, pits of varying size up to half an inch, often coalescing. Many fruits were so severely attacked that from a half to three-quarters of the surface was cankered. Fruit of all sizes was attacked, and when seriously infected dropped to the ground, leaving the pedicel still attached to the plant. The conidia occurred in salmon-pink masses (*sporodochia*) clustered in the bottoms of the pits.

It is not likely that spraying will avail against this disease. Resistant or non-susceptible varieties properly cultivated and kept free of nematodes or other weakening agencies will prevent serious loss.

WILT OR CROWN ROT (*Sclerotium rolfsii* Sacc.)—Several plants were killed by this fungus early in the season. The cases observed were all very characteristic. There was a rotting of the roots and of the bark at the crown, accompanied by production of white mycelium both on the roots and at the base of the stem. Later brown sclerotia appeared around the crown and on the surface of the soil adjoining. When occurring together with root-knot, death of the plant was especially rapid. *Scleria pterota* and *Alternanthera sessilis*, weeds growing adjacent to the eggplant, were found attacked in one instance.

LEAF SPOT, FRUIT ROT (*Phomopsis vexans* [Sacc. & Syd.]) Harter.[1]—This fungus caused a leaf spot, fruit rot and stem blight or canker of the New York spineless variety grown in the second planting. As a leaf-spot fungus it has been commonly known as *Phyllosticta hortorum* Speg. Neither the anthracnose nor other diseases were observed on this variety. Commercially the crop was a total failure as a result of the combined attacks of this fungus and insects.

[1] Identification verified by Mr. L. L. Harter, Pathologist, Bureau of Plant Industry, U. S. Department of Agriculture.

Bordeaux and lead arsenate applied at intervals of a week sufficed to check the disease to some extent and to stop the insect attacks, but were of no practical value. No salable fruit was obtained.

On the leaves this disease occurred as brown spots, varying considerably in size and shape. On seedlings in flats they were small, hardly over one-eighth inch in diameter, more or less circular, and attacked the older, lower leaves. At this stage it appeared to be merely a disease of old over-mature leaves, or of plants held too long in the flats and so weakened. However, the disease appeared on plants in the field, causing large irregular, dull-brown spots on the leaves and brown, sometimes sunken, lesions on petioles and young stems. Branches or twigs were often girdled, and in some plants this was so common that nothing remained alive beyond a short length of the main stem. The fungus produced nearly circular, raised areas on the fruit, hardly different in color at first from the normal skin of the fruit, but soon coalescing to form black areas covering large portions of the surface area. The calyx lobes and pedicels were also often attacked, resulting in irregular, sunken brown cankers. In all diseased areas the fruiting bodies appeared as minute black points, but were especially prominent in the fruit and stem cankers. There was at first a soft rot with same leaking, and the fruit very soon fell to the ground, leaving the infected pedicel and calyx on the plant. Within a short time it became a black, wrinkled mummy.

Fruit Rot (*Diplodia* sp.)—Fruit of the long purple variety was rotted by a species of *Diplodia* not at present distinguishable from *Diplodia natalensis,* the cause of stem-end rot of Citrus. Innoculations have not yet been carried out. The fungus apparently attacked through the stem end, causing the fruit to drop to the ground, where it was soon mummified by a dry rot. The pedicel and calyx remaining on the plant had much the same appearance as when attacked by *Phomopsis.* There were first brown lesions followed by death and complete withering and drying. The rot of the fruit progressed very rapidly to the blossom end, appearing, externally medium brown in color, internally light brown, with no juice exudate. Only young fruit were observed attacked. The pycnidia produced in a damp chamber resembled those of *D. natalensis* on Citrus.

Root Knot (*Heterodera radicicola* [Greef.] Mül.)—Some few plants were attacked by root knot. Except where *Sclerotium Rolfsii* was also present no perceptible damage resulted, although the plants were undoubtedly weakened by the presence of these parasites.

A *Nectria* sp. was found at the base of a plant that had been killed by *Sclerotium,* so that it can be considered only as a sapro-

phyte. There were no other disease symptoms than those due to the *Sclerotium*.

Damping-off of seedlings in flats was due to *Fusarium* sp. Care in watering and in the use of sterile or new soil should obviate this trouble.

Henricksen (5) reports bacterial wilt (*Bacillus solanacearum* Sm.) as very common. Such cases of wilt as have been found in the present investigation were, however, in all cases easily attributable to *Sclerotium* and root knot.

Gandul, Pigeon Pea (*Cajanus indicus*).

The gandul or pigeon pea is subject to a number of fungus diseases which tend to shorten the life of the plants.

One of the commonest is *Cercospora Cajani* P. Henn., causing a leaf spot. The spots are numerous, subcircular to irregular, medium brown in color, margin indistinct, appearance much the same on both surfaces. Affected leaves are shed sooner than normal ones.

Rust (*Uromyces Dolicholi* Arthur).—The rust, while quite common, causes very little damage. It is characterized by small, deep-brown, powdery pustules on the lower leaf surfaces.

A very serious stem canker, apparently due to a fungus not yet determined, has been observed in several localities, but studies have not been carried out. Numerous other fungi aid in the death and rotting of stems of mature plants, notably *Megalonectria pseudotrichia*[1] and others of the same group.

Lettuce (*Lactuca sativa*).

Leaf Spot (**Cercospora lactucae n. sp.**)—But one disease was found on lettuce and that of minor importance. This was a leaf spot due to an apparently new species of *Cercospora*, which is described below. The fungus attacked principally the older and lower leaves and caused slight injury as long as the leaves were gathered regularly. At the time of production of the flowering stalk, however, it rapidly spread to all leaves and, the numerous spots becoming confluent, practically the entire leaf surface of the plant was destroyed.

Cercospora lactucae sp. nov.—Spots amphigenous, drab (Ridgeway, Plate XLVI), subcircular to angular, slightly sunken, with definite margin (not raised), one to eight millimeters in diameter, often confluent especially along margin and tip; conidiophores amphigenous, fascicled, few (four to ten to each fascicle), simple, four

---

[1] Determined by Dr. F. J. Seaver, of the New York Botanical Garden.

to eight septate, 15–50 by 5–7 mu., medium brown, tips paler; conidia clavate to long clavate, often curved, hyaline to smoky, six to twelve septate, tips often non-septate, 3.5–5 by 50–100 mu.

On leaves of *Lactuca sativa* L. in Porto Rico: Río Piedras, 6244 (type), 5071, 5613.

Marimbo, Gourd (*Lagenaria leucantha*).

A leaf spot (*Cercospora cucurbitae* E & E) occurred on this host. The spots were numerous, nearly circular, up to eight millimeters in diameter, brown at first, becoming dull white or tan at the center, with a slightly raised, definite margin, and red brown in color, causing the death of the older leaves.

Muskmelon (*Cucumis melo*).

The growing of melons has been as little successful as that of cucumbers. Several diseases are in large measure responsible for this condition, although unsuitable varieties and poor cultural practices must be blamed in part.

On the early (December) plantings the downy mildew (*Pseudoperonospora cubensis*) was especially virulent and accounted for the death of the plants. Spraying with Bordeaux mixture (3–3–50) was without apparent effect. The symptoms were the same as on cucumbers.

Anthracnose (*Colletotrichum lagenarium* [Pass.] Ell. & Hals).—Plantings made later in the season were subject to other leaf diseases, and while not so quickly destructive as the mildew they were quite effective in cutting down the yield to practically nothing. The most important of these was the anthracnose which appeared as irregular brown spots or patches on the leaves. These soon coalesced causing the death of the entire leaf. Often the centers of the diseased areas dropped out leaving large ragged holes. Lesions on petioles and stems were also produced. This disease has been reported as serious on the fruit and would doubtless have proved so in this case if there had been fruit present in any amount.

Occurring sometimes in the anthracnose spots and at other times alone, another fungus was found, *Phyllosticta citrullina*. Spots caused by this fungus were light brown, nearly circular, and with the minute black fruiting bodies (pycnidia) clustered at the center. Of minor importance.

Chlorosis.—One case of chlorosis was found in which an entire plant had taken on a yellow color, portions of the stem only re-

maining green. The leaves were small, wrinkled and thicker than normal. Inoculations with material from this plant on other non-chlorotic plants were without result because of the death of the plants from other diseases.

Mustard (*Brassica* spp.).

The common mustard grown chiefly for the leaves, which are used as greens, is subject to several leaf diseases. The white rust (*Albugo candida* [P.] Rouss.) is common, producing numerous white pustules on the lower leaf surfaces.

A leaf spot (*Cercospora bloxami* Berk. & Br.) causes the death of the leaves in many cases. The spots are at first nearly circular (hardly spherical as given in one description), white or dull yellow in color and up to half a centimeter in diameter. They very soon run together, however, destroying the leaf.

Okra (*Hibiscus esculentus*).

Okra was commonly subject to a leaf disease due to *Cercospora hibisci* T. & Earle). This fungus did not occur in definite spots, but rather in indefinite sooty patches often confluent on the lower surfaces of the leaves. The leaves were sapped of their vitality, turned yellow and dropped. The result was a tall stem, bare of leaves except at the tip and bearing very little fruit. No experiments for control have been tried.

Onion (*Allium cepa*).

Onions are raised to a considerable extent in the western part of the Island. Opportunity, however, has not been had to examine any of the plantings. Reference is made by Henricksen (5) to smut (*Urocystis cepulae* Frost) and to downy mildew (*Peronospora Schleideniana* De Bary) but without definitely reporting them as present in Porto Rico.

Pea (*Pisum sativum*).

Wherever observed the garden pea has been subject to powdery mildew (*Erysiphe polygoni* Dc?). This fungus formed a thin gray or white coating over leaves and pods, and while it did not actually kill the parts attacked, it checked the growth and so lessened the yield. In common with all other powdery mildews collected on various plants, wild and cultivated, the conidial stage only was found. This disease could be readily controlled if necessary by Bordeaux, or other fungicide.

In one instance a leaf spot due apparently to *Cercospora* sp. has been collected. The spots were small (two to three millimeters in diameter) amphigenous, circular to angular, without a definite margin, dull brown to gray, often coalescing and causing a yellowing and subsequent death of the leaf. Fruiting on both surfaces. Conidia hyaline, long clavate, strongly septate. If, as appears certain now, this species is undescribed, a complete description and name will be published later, together with more complete notes on the nature and amount of injury caused by it.

Peanut (*Arachis hypogea*).

The peanut was subject to two leaf diseases, both quite effective at times in reducing the yield. Other diseases due to *Sclerotium Rolfsii*, or to other root-rot or wilt inducing fungi, have not been observed, but doubtless occur, or will with any extension of planting.

Leaf Spot (*Cercospora personata*).—The leaf spots caused by this fungus were nearly circular, brown to black with an indefinite margin, and generally numerous enough to practically cover the leaf surface. The lower leaves were attacked first, but the others soon succumbed in turn. It was difficult to estimate the damage, some growers declaring that the disease appeared after the crop was practically mature and that hence no damage was done.

Rust (*Uromyces arachidis*).—This fungus attacked all varieties, causing innumerable small golden brown to dark-brown pustules on both sides of the leaves, in many cases practically covering them and undoubtedly doing some harm since the effective leaf surface was reduced. In fact, experiments in the British West Indies have shown that decreased yields do result from attacks of this disease. Spraying with Bordeaux at intervals of a week was reported to have been without effect in checking or controlling either of these diseases.

Pepper (*Capsicum annuum*).

Fruit Rot.—The peppers of the first planting (Neapolitan) remained comparatively free of this trouble, but those of the second were seriously attacked. These varieties were Sweet Mountain, Large-bell, Chinese Giant and Ruby King, all of which were attacked to about the same degree, in so far as preliminary observations of one year show. At the time the first picking was made a large percentage of the fruit was found to have on one side or at the blossom end rotted areas. These were in general medium to light brown in color or at times nearly white, with definite margins and often sunken.

The affected tissues were softer than the normal, but still quite firm, and there was no juice exudate. In many cases the spots had all the appearance of sunburn or other non-parasitic causes. Fruit so affected soon dropped, unaffected portions turning a deep red and the whole fruit ultimately mummifying. It was noted that the fruit of certain plants remained comparatively free of the disease, while all of the fruit on other plants was affected, the weaker plants apparently. Certain fungi were commonly found associated with the spots, in particular *Cladosporium herbarum*, *Fusarium* sp., *Pestalozzia guepinia*, and *Macrosporium* sp. *Macrosporium* sp. is ordinarily considered the cause of a serious rot of peppers, but in the present instance it was found in so few cases that it is grouped temporarily at least with the other forms. Further work is necessary to ascertain the exact relations of these fungi to the disease. This may result in the division of the disease into both parasitic and non-parasitic types as is suggested by observations to date.

Anthracnose.—In the early stages it was not always possible to distinguish this disease from the above. In general, however, it was marked by more nearly circular areas, often several on one fruit, and more definitely sunken. The spots showed first as water-soaked areas turning brown. The fruit ripened prematurely, became shriveled, but quite often remained hanging to the plant. Two fungi were found in connection with this disease, *Gloeosporium piperatum* E. & E. and *Colletotrichum nigrum* Ells. & Hals., which after further work may prove to be the same, the presence or absence of setae in the fruiting bodies being the only point of difference, which is a doubtful character at best. At the first report of trouble with fruit rot spraying with 3–3–50 Bordeaux was commenced and continued at intervals of a week until eight applications had been made. Counts were made of the diseased and sound fruit at each picking. At no time was it possible to find any constant difference in amount of disease between sprayed and unsprayed areas. The percentage of spotting at first very heavy, gradually declined through the season, due apparently to cultural and climatic reasons; certainly independent of the spraying.

Wilt (*Sclerotium Rolfsii* Sacc).—This common disease of sugar cane (red rot of the leaf-sheath) attacked several of the vegetables and was especially serious on the peppers. Plants attacked by this fungus exhibited first a slight drooping of the leaves exactly as occurs when there is a shortage of water. The wilting increased each day with partial recovery at night until at the end of four or

five days the plant was practically dead. Examination of wilting plants showed healthy tops, but further search revealed brown sunken lesions at the crown, which grew rapidly until the stem was girdled and death resulted. A scanty white mycelium was generally present in these areas spreading down along the roots for some distance, rotting and killing them, as well as out over the surface of the ground, attacking weeds or other plants with which it came in contact. At the base of the diseased plant, there was in most cases an abundant production of the so-called sclerotia or fruiting bodies, yellow to dark brown, nearly spherical bodies, of about the size of mustard seed. Sclerotia from peppers produced typical cases of red rot of the leaf-sheath when transferred to cane.

All four varieties of the second planting were attacked and to about the same degree. The loss was greatest in the lower ends of the rows where there was possibly more moisture, although plants in all parts of the field were lost. About three per cent of the plants were killed.

Leaf Spot (*Cercospora capsici* H. & W.)—This leaf spot was most abundant and was collected or observed in numerous localities. The determination is provisional. The spots were circular, varying in size from a sixteenth to half an inch in diameter and were often very numerous. Their appearance was the same on both sides of the leaf, not raised, but rather slightly sunken with definite margins. The color was a dark dull brown with dirty white center and a surrounding faint halo of yellow. Centers of old spots often broke out irregularly. All varieties were very subject to attack. Older and lower leaves were first infected, turned yellow, and dropped. At times no further damage occurred, but quite often nearly complete defoliation resulted.

This disease was readily controlled by Bordeaux mixture. No spotting occurred on sprayed rows.

Root Knot (*Heterodera radicicola* [Greef] Mül.)—Peppers are very much subject to root-knot and serious damage often results. The trouble is prevalent in many parts of the Island. See under tomato.

Potato (*Solanum tuberosum*).

Potatoes do not thrive, at least in the lowlands, and it is extremely doubtful whether any results can be hoped for in any part of the Island. A root rot has been reported (1), and the opinion is there given that the disease will prevent the growing of potatoes in Porto Rico. The fungus concerned was not determined.

Roselle (*Hibiscus sabdariffa*).

Barrett reported (3) a root rot of this plant, possibly due to bacteria. Not observed in the present investigations.

Sesame (*Sesamum orientale*).

This plant, locally known as "ajonjolí," is commonly subject to a leaf spot attacking particularly the lower leaves, although instances have been observed of mature plants which had been practically defoliated. The spots, due to *Cercospora Sesami* Zimm, are very numerous, small (not over two millimeters in diameter) subcircular to angular, dull white to gray, with a definite, slightly raised deep brown margin. Sporulating on the upper surface.

Squash (*Cucurbita moschata*).

In so far as observed this crop was free of disease, even when in proximity to other cucurbitaceous plantings, such as cucumbers or melons. Henricksen (5) reports downy mildew as an enemy of the squash.

Sweet Potato (*Ipomoea batatas*).

The sweet potato is one of the most common of the native crops, and while no large plantings are made the total of the innumerable small patches is considerable. As is usual with a crop which is not planted in large or continuous areas, serious diseases seem to be lacking. There have been reports received of losses, but in so far as it has been possible to discover from specimens submitted, insects have been to blame. However, it is known that some at least of the dry rots reported for other countries do exist here, and an effort will be made to find them.

White Rust (*Albugo ipomoeae-panduranae* [S.] Swing.)—Only three fungi have been encountered on this host, all leaf parasites. The most common of these was the white rust, which caused indefinite spots varying from the size of a pinhead to half an inch or more in diameter. At times whole leaves were deformed and swellings produced on stems and petioles. The spots were yellow to brown above, and below showed the white pustules formed by myriads of spores. All of the various types or varieties of sweet potato, both cultivated and wild, have been found subject to attack.

Leaf Spot (*Phyllosticta batatas* E. & M.)—In one instance leaf spots due to this fungus were found. The spots were circular to angular, up to one-quarter inch in diameter and light gray in color

with a definite brown margin. The minute black pycnidia were clustered at the center.

Rust (*Coleosporium Ipomoeae* [Schw.] Burr).—The rust was of common occurrence but cannot be considered of any economic importance. Small yellow pustules broke out on the under side of the leaf.

Two species of sooty mold (*Meliola clavulata* Wint. and *Meliola Ipomoeae* Earle) occur on this host, but without causing apparent injury.

Tomato (*Lycopersicon esculentum*).

The tomatos in the test plots as well as those observed in gardens about the Island have suffered most severely from a number of diseases, which can be held responsible in large measure for poor yields obtained in some cases and the failures in others. There is again to be noted the occurrence of different diseases at different seasons of the year.

Leaf Mold (*Cladosporium fulvum* Cke.)—This fungus also occurs commonly on the wild berengena (*Solanum torvum*), a very common weed in all parts of the Island. All varieties of tomatos (Trophy, Livingstone globe, and Ponderosa) in the first planting (December-February), as well as those in other gardens growing at this time of the year were attacked. The disease commenced in the shelter of the windbreak and spread very rapidly over the entire garden. The lower leaves were attacked first, but with little delay the balance of the plant was infected, only the very tips remaining free. Diseased leaves soon withered and dropped with the result that the plant consisted of but a few long spindling stalks devoid of mature leaves or fruit. Removal of diseased leaves was without effect in checking the spread of the fungus.

Spraying with Bordeaux was commenced before the *Cladosporium* appeared, and although various strengths, combinations with lead arsenate, and different kinds such as paste, powder, and home-made solutions were tried, no differences were at any time observed between sprayed and unsprayed rows. The number of sprayings varied from three to eight on the different plots and were at intervals of a week except in one instance, twice a week.

The fungus was virulently parasitic, occurring on the lower surface of the leaves in irregular velvety patches, which were white at first, then brown, and finally nearly black. The various patches soon coalesced by which time the leaf was yellow and curling.

This disease was not found on any of the varieties grown in the

second planting (April-June). *Solanum torvum* was also present in abundance at this time, but was free of disease.

LEAF SPOT (*Septoria lycopersici*) Speg.—This fungus caused very definite spots in contrast to the effuse irregular areas of the *Cladosporium*. The spots were more or less circular, appeared the same on both sides of the leaf and were quite small, hardly ever more than one-eighth inch in diameter with a definite dark brown margin. They were brown to nearly black with the minute black fruiting bodies (pycnidia) at the center. When the spots became numerous, as was the case with all the varieties of the first planting, the leaves turned yellow, curled, and dropped. Lower leaves succumbed first. In combination with leaf-mold this disease was the cause of much damage through defoliation and consequent reduction of yield. Some few fruit only were found bearing the characteristic spots. It was especially a disease of young plants in flats or pots, tending to produce weak spindling plants, which if not entirely ruined by this cause remained weak or fell easy prey to other destructive agencies. As noted in the leaf-mold discussion, spraying and other measures were of no avail.

In the second planting *Septoria* appeared only after the plants were well advanced in contrast to its attack of the plants of the earlier crop in the seedling stage. It did not prove serious. Lower leaves were killed, and together with the *Phoma* spot some dying of the upper leaves occurred, but in no way to be considered serious. Spraying was again without effect.

BLOSSOM-END ROT.—Considerable trouble was experienced with a blossom or point-end rot, which was apparently due to cultural conditions rather than to any parasitic organism. A *Fusarium* sp. quite commonly occurred in the rotted areas, but it is not likely that it was other than saproyhytic since it was generally present in advanced cases only and sometimes not at all. It formed pink and white masses of mycelium and conidia over rotted areas.

The rotted areas were medium brown in color, nearly circular, at first limited to a small area around the blossom end, but soon enlarging until one to two inches in diameter, at about which time the fruit dropped. The spots were only slightly sunken if at all and but little softer than normal tissues until secondary decay set in due to bacteria or saprophytic fungi. All varieties of the first planting were subject, the loss running around ten per cent. The trouble was not experienced in the second planting, possibly due to more satisfactory moisture or cultural conditions.

SOFT BROWN ROT.—In the second crop there was some loss from

a soft brown rot apparently due to an undetermined fungus of the *Phycomycetes* or alga-like fungi. This occurred more commonly on fruit hanging close to the ground or actually in contact with it. In the latter case there was a surface growth of white flocculent mycelium. The rot commenced as a discolored or water-soaked area, soon becoming dull brown and spreading irregularly over the balance of the fruit, accompanied by a heavy exudation of juice.

ANTHRACNOSE (*Colletotrichum phomoides* [Sacc.] Chester).—Some few cases of this disease on ripe fruits were collected. It caused sunken, circular areas on the side or end of the fruit, often of considerable size, in which appeared the pink (or in advanced cases black) conidial masses. Of slight importance.

Following cracks, insect and mechanical injuries or other wounds bacterial soft rot was common.

ROOT-KNOT, NEMATODES (*Heterodera radicicola* [Greef] Müll.)—The losses due to the attack of this minute worm have been heavy and much more in fact than is generally realized because of the fact that it works below ground. Attacks by this parasite will explain to some extent, it is thought, the weakness of not only the tomatos but of other crops permitting leaf and fruit parasites to make headway in spite of spraying or other preventative measures. In the Station plots tomatos suffered most severely, but eggplant and peppers were also attacked. At the end of the season examination showed a hundred per cent infestation of all varieties, certain ones, however, maintaining growth in spite of the nematodes and even giving a crop of fruit.

Where death occurred, the first symptoms were a slight wilting of the upper leaves, which increased until within a few days the entire plant was involved and death ensued. Upon pulling a wilted plant, the roots were found malformed or to consist of a series of enlargements or galls. Within these swellings the presence of the parasitic worms or nematodes in various stages was easily demonstrable with the microscope. Various fungi contributed to the death of attacked plants and speedily rotted away roots and crown, liberating a new brood of worms into the soil, so that in old cases nothing remained but the woody tap root and fragments of secondary roots and galls. The nematodes liberated in this manner remain in the soil for a number of years and are capable of reinfesting any new plants that may be set out.

Certain varieties in particular of the second planting, namely, Stone, Duke of York, Matchless, and Beauty were practically destroyed, the potting soil having been infested apparently. It was

noted that those supplied with manure survived, which suggests a means of control by supplying improved cultural conditions together with care in avoiding infested soil. Where possible infested soil should be sterilized by steam or by fire before using in flats or pots. This will insure healthy plants.

Black Spot (*Phoma destructiva* Plowr.)—The Livingston Globe variety and to a less extent other varieties in the second planting were attacked by this recently described disease (6). The spots, similar on both sides of the leaf, were brown with a definite dark brown margin, circular at first, then irregular, and finally confluent, causing the death of the leaf. Very few spots were found on the fruit, and these apparently following injuries from other causes, sucking insects, etc. The fungus agreed with the description given of *Phoma destructiva*.

Wilt (*Bacillus solanacearum* Erw. Sm.)—This serious disease has on several occasions been reported from Porto Rico (1) and doubtless does occur on tomato as well as on other related plants, but it has not been found in the present investigations. In the brown-stained vascular tissues of the lower portion of the stalks of plants killed by nematodes, bacteria were present, but were not capable of independently causing wilt of otherwise healthy plants. Nematodes were the causes of all cases of wilting which it has been possible to examine.

Minor Troubles.—Splits and cracks were very common. They can doubtless be attributed to extremes in the water supply, a drouth followed by excessive rains, excessive fertilization, and the like.

One case of rosette was observed. No cause was discerned nor was the juice of the plant infectious.

"Damping-off" of seedlings occurred as with eggplant and due apparently to the same cause.

Phytophora infestans Mont (De Bary) (Downy Mildew) has been reported from near Maricao by Prof. Whetzel and Dr. Olive, but has not been with certainty seen here. It is also reported by Henricksen (5).

Turnip (*Brassica campestris* and *B. Rapa*).

A leaf spot (*Cercospora Bloxami* Berk. & Br.) is reported (11) on this host. This is the same fungus as given under mustard. Not serious.

Black rot (*Bacterium campestris* Er. Sm.) is also reported (5) but has not been encountered by us.

Watermelon (*Citrullus vulgaris*).

The leaf spot (*Cercospora citrullina*) mentioned in the last report (10) continues to be present and through the killing of the leaves is most effective in reducing yields. Also reported from Mayagüez (5).

Blossom-End Rot.—This year a blossom-end rot of the fruit was observed. The blossom end of a fruit attacked by this disease dried up and turned brown, although the remainder of the fruit sometimes continued to enlarge for some time. Fruit of all sizes were attacked. Various fungi gained entrance and set up a soft rot with juice exudate. *Diplodia* sp. was found in several instances associated with this rot and also as the apparent cause of a stem-end rot in one case. No studies have been made of this fungus.

It was observed that this trouble was most prevalent during a drouth, but that later when the plants were growing vigorously under the stimulus of an abundant water supply, it practically disappeared. Irrigation or frequent cultivation will doubtless check the disease fairly well.

Yautía (*Colocasia* sp., *Xanthosoma* sp.)

The yautías were quite subject to a disease known as ''El mal'' and probably due to a vascular parasite, although there was no opportunity to investigate it. Plants attacked by this disease failed to thrive, the leaves remained small, and were generally yellow. The yield was greatly reduced. The disease was favored by poor soil and dry weather. It can be avoided by care in planting only healthy ''heads'' or offsets in uninfected soil.

Phyllosticta colocasicola Höh. has been reported (7) on Colocasia sp. Other fungi (*Periconia* sp. and *Gloeosporium* sp.) are mentioned as occurring in spots on *yautía*. Of minor importance.

CONCLUSION.

Studies to date have been merely preliminary, a survey of the field as it were. However, certain points have become clear as regards the presence of diseases. It can be taken for granted that they will appear, and consequently all steps possible should be taken to control or minimize their attack. Most of the problems must be met by producing or introducing resistant varieties, a proposition for the plant breeder and one that requires time. Much can be done, however, and fair crops of most vegetables realized by following such corrective measures as are now known, such as proper preparation

of seed beds, thorough cultivation, irrigation and drainage, and the destruction of weeds.

After each crop all old plants and débris should be burned and a proper rotation maintained. Spraying with the various fungicides will be found of value for many of the diseases.

LITERATURE CITED.

(1) Barrett, O. W.—1903. Report of the Entomologist and Pathologist. *In* Annual Report of the P. R. Agric. Exp. Sta. for 1903, pp. 449–450.

(2) Barrett, O. W.—1904. Report of the Entomologist and Pathologist. *In* Annual Report of the P. R. Agric. Exp. Sta. for 1904, pp. 397–399.

(3) Barrett, O. W.—1905. Report of the Entomologist and Pathologist. *In* Annual Report of the P. R. Agric. Exp. Sta. for 1905, pp. 22–23.

(4) Barrett, O. W.—1905. Diseases of Yautía. *In* Bul. 5 of the Porto Rico Agric. Exp. Sta., pp. 22–23.

(5) Henricksen, H. C.—1906. Vegetable Growing in Porto Rico. Porto Rico Agric. Exp. Sta. Bul. 6, pp. 9–58.

(6) Jamieson, Clara O.—1915. Phoma Destructiva the Cause of a Fruit Rot of the Tomato. *In* Jour. Agr. Research, vol. 4, No. 1, pp. 1–20.

(7) Young, Esther.—1915. Studies in Porto Rican Parasitic Fungi–I. *In* Mycologia, vol. 7, No. 3, pp. 143–150.

(8) Arthur, J. C.—1915. Uredinales of Porto Rico. *In* Mycologia, vol. 7, No. 4, pp. 168–196.

(9) Garman, Philip.—1915. Some Porto Rican Parasitic Fungi. *In* Mycologia, vol. 7, No. 6, pp. 333–340.

(10) Stevenson, J. A.—1915. Report of the Pathologist. *In* Fourth Report of the Board of Commissioners of Agriculture of Porto Rico, pp. 33–34.

(11) Young, Esther.—1915. Studies in Porto Rican Parasitic Fungi–II. *In* Mycologia, vol. 8, No. 1, pp. 42–46.